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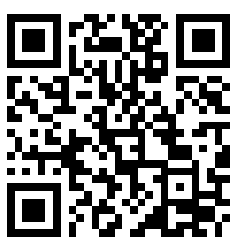

TECHNICS

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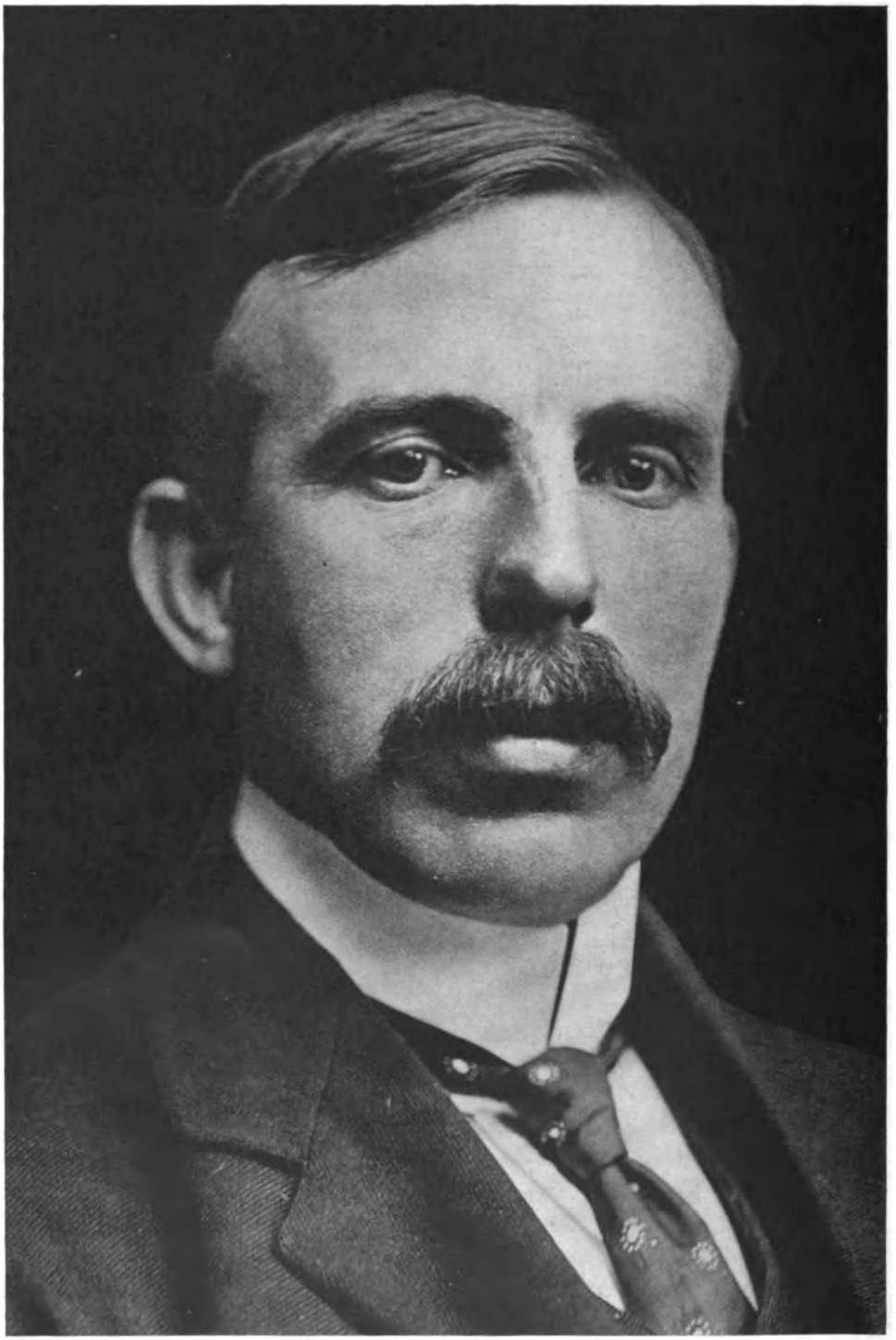

ERNEST RUTHERFORD, M.A., D.Sc., F.R.S.

(The discoverer of many important properties of Radium).

Photo. by Geo. Newnes, Ltd.

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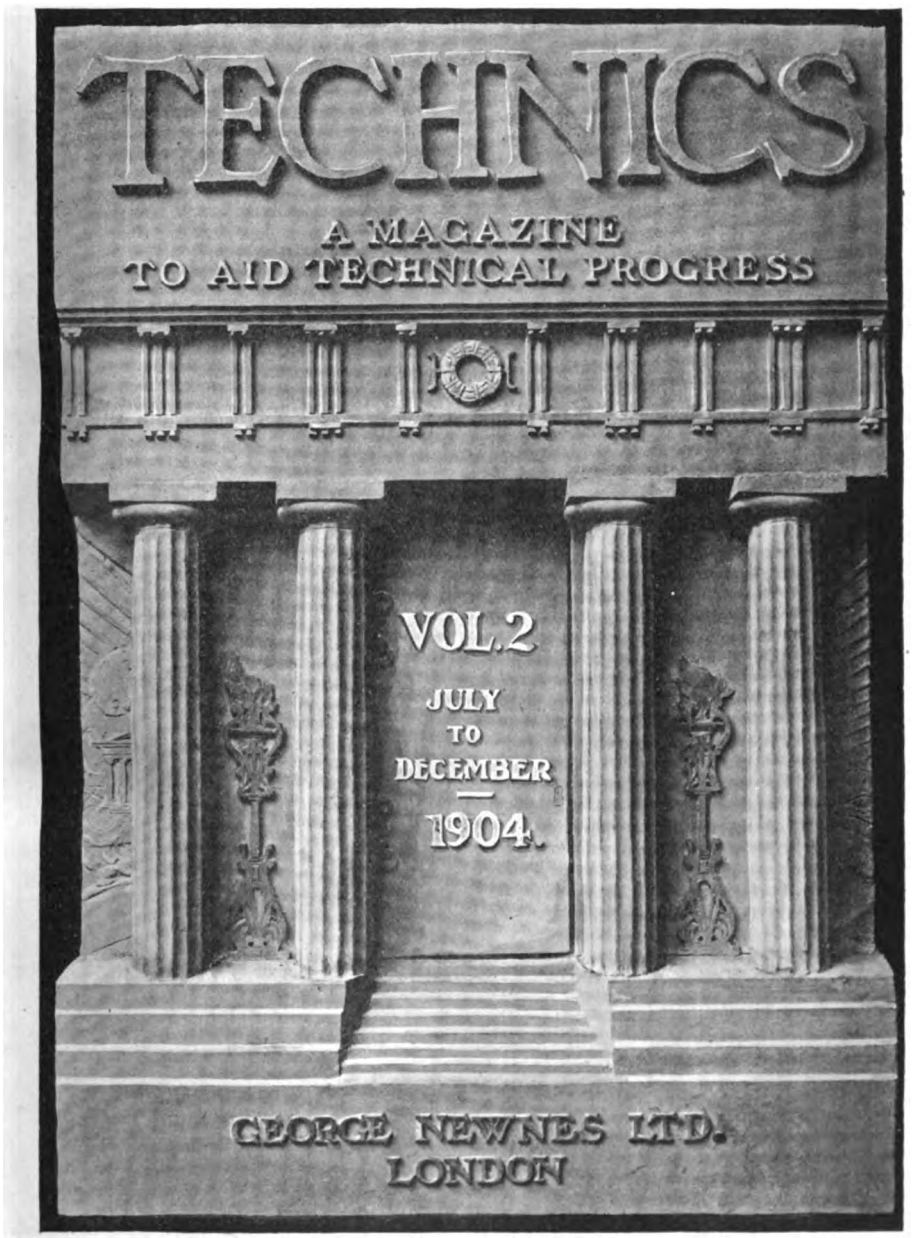

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. II. JULY, 1904. NO. 7.

PROGRESS OF SCIENCE AND TECHNOLOGY.

THE suggestion of Rutherford and Soddy, that helium might be regarded as a decomposition product of radium, was based on the general presence of the gas in radio-active minerals. The recent investigations of Ramsay and Soddy have shown that although a transient helium spectrum can always be obtained from the gases liberated by radium, the quantity produced is so small that the evidence would probably have been regarded as negative if the liberated gas had been any one of the commoner constituents of the atmosphere. That the phenomena are somewhat complex is shown by the simultaneous liberation of oxygen, hydrogen, nitrogen (in Professor Curie's experiments) and carbon dioxide; and further experiments with larger quantities of radium salts, completely freed and kept free from air and moisture, are greatly to be desired.

Helium as a Decomposition Product of Radium

BY a very similar line of argument it has been suggested that radium is itself a decomposition product of uranium, the latter being the main constituent of practically all the radio-active minerals. This may be regarded as a final stage in the disintegration theory of radio-activity, and gives to it a completeness that was formerly somewhat lacking. The main result of this addition to the theory is to explain the continued presence of so short-lived an element as radium at this late stage in the earth's history; but it also explains the fact that the proportion of radium, though always small, is comparatively uniform. Polonium, which is more active, and therefore more short-lived, is regarded as an intermediate decomposition product of radium, and is present in even smaller proportions.

Radium as a Decomposition Product of Uranium

THE climax of activity is reached in the emanation, which wears itself out in a few hours. Ramsay and Soddy have estimated that 60 mg. of radium bromide normally contain about 0·03 cubic mm. of emanation, and this small quantity of gas is responsible for 75 per cent. of the heating effect of the radium salt, amounting to about 100 calories an hour per gram of elementary radium. From these data it can be deduced that a cubic centimeter of the emanation would yield energy to the extent of 10^7 calories as compared with 2 calories for a cubic centimeter of hydrogen and oxygen. This concentration of energy is perhaps the most remarkable of all the phenomena exhibited by the radio-active elements.

The Energy of the Radium Emanation

SIGNIFICANT news comes from the circles of the German technical employees. No less than 2000 engineers, technical men, chemists, etc., of all callings and degrees of ability, from engineers with diplomas and academical training and from fully qualified chemists, to draughtsmen, have combined for the purpose of forming a large, far-reaching organisation for themselves as industrial workers. The following has been written from an authoritative source:—"We bring to the knowledge of our colleagues, and also give it wide publicity, that we have founded some days ago a trades organisation under the name of the 'Bund der industriellen Beamten' (Arbeitnehmerbund), or Union of

Organisation of Technical Employees

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Technical Employees, located in Berlin, for the purpose of counteracting any further prejudice to the condition of technical workers in industrial life. Our union will not be a club, but an organisation; without any political features, though with a strongly marked economical tendency. Our programme for rehabilitation of the technical employees question is, alas! very large. Through most open activity and the strength of this union, we shall strive to assure for ourselves that protection which has been granted to every workman by his employers and the Government. In the first place, it is our duty to provide for a central employment bureau, and a fund for the support of needy members, who are out of employment through no fault of their own. In carrying out our difficult project, we are counting on the assistance of the whole of the Press, which up to the present has remained silent, as well as on the active co-operation of all employers who take an interest in the welfare of their employees; but, before all, on the complete co-operation of all our colleagues who, like us, are convinced that the time has now arrived when we must do something to help ourselves in order not to endanger our social existence still further." The place of business in Berlin, W. Potsdamerstrasse 70A, receives names and also gives necessary information.

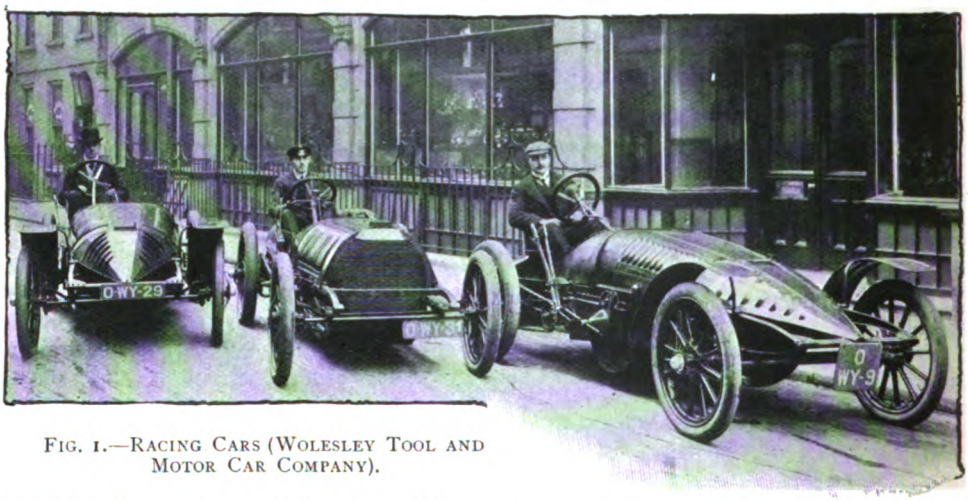

FIG. 1.—RACING CARS (WOLESLEY TOOL AND MOTOR CAR COMPANY).

Racing Cars

FIG. 1 represents the type of racing car manufactured by the Wolesley Tool and Motor Car Company; a car of this type was driven by Mr. C. Jarrott in the English team competing for the Gordon-Bennett Cup in Germany. The frame is pressed from sheet steel, and is of channel section. The principal dimensions are:—

Wheel base, 9 ft. × 4 ft. 7 ins. track.
Rear wheels, 36 ins. × 5 ins.
Front wheels, 34 ins. × 3½ ins.

The motor comprises four cylinders in line, giving 96 h.p. at 96 revolutions per minute; it can, however, be run at a speed as high as 1,300 revolutions per minute. The coil comprises two tremblers, either of which may be used at pleasure, by means of a suitable cross-over switch. An external spark gap is provided in each high-tension circuit. The carburettor is of a special type, designed to keep the mixture of air and petrol vapour constant at all speeds. One jet serves all four cylinders. Ball bearings are provided for the crank shaft, and are arranged so as to be unaffected by any springing of the frame. Hand and foot brakes are provided, both acting on the hind wheels. The foot brake is of the expanding type, while the hand brake is of the band type. The normal speed of the motor (96 revolutions per minute) is equivalent to a car speed of 75 miles per hour. We are informed that Mr. Jarrott considers this car to give easier riding at high speeds than any other car he has ridden.

The Electrification of Main Line Railways

ONE of the most difficult problems at present engaging the attention of engineers, is that of the electrical operation of main line railways. Most of the steam lines are experiencing heavy losses in their suburban traffic, owing to the competition of electrically operated urban and suburban

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tram lines; thus it is natural that the substitution of electricity for steam as a motive power should be looked to as a remedy. Nevertheless, the difficulties to be overcome are very serious. For main line through express trains, it is probably at present impossible to demonstrate an economic gain due to the substitution of electricity for steam as a motive power; since an express train, in the course of its journey, covers long distances over which an exceedingly infrequent local service suffices. With a train once every hour, or even every half-hour, requiring many hundreds of horse-power during the few minutes of its passage through a certain section, it is almost impossible to show sufficient earnings to cover the heavy capital expenditure for the generation and distribution of the electrical power. This is fairly evident from the following considerations: The generating and transmitting systems will entail a very high capital expenditure per mile of single track. This great capital expenditure will, moreover, be unproductive for a great part of the time; whereas the far lower capital expenditure for locomotives is constantly productive throughout the life of the locomotive.

It is for just such remote but extensive sections of track that the operating expenses, when using electricity as the motive power, will be abnormal. For while an express train, during its passage over a given section of line, requires from one thousand horse-power upwards, to be supplied to the corresponding section of the conducting system; this is followed by an interval of zero consumption, lasting until the next train enters the section. The local sub-stations, since each would supply but a single section, must be *absolutely* idle during this long interval, and even the power station which would supply the sub-stations of several sections, would have an exceedingly low load factor. At the power station it would be necessary to provide generating plant of a total capacity at least four times greater than the average load, and this plant would show but a very poor economy. The greater part of a large railway company's main line is only used to the extent of some few thousand train-miles per year per mile of single track; and on these sections, electricity as a motive power could not be expected to show an economy at all approaching that attainable with steam locomotives.

A similar consideration of the conditions in the immediate neighbourhood of large cities, and on lines connecting neighbouring large towns, will show a decided advantage for electrical operation, in spite of the necessarily heavy outlay. For on these sections the use of electricity as a motive power favours short trains at intervals of but a few minutes. The load factor on the generating plant would be high; but only a small portion of the capital investment would be idle for any length of time, and the trains would be heavily loaded. A suburban train may be counted upon for carrying, on the average, nearly or quite one passenger per ton hauled; but through expresses would probably not average over one-fourth of a passenger per ton hauled.

Electricity v. Steam on Railways

NOTHING short of the most exhaustive analysis in each particular case can determine the economy of substituting electricity for steam; and even then the result is largely speculative, for the cases on record are still so few that the factor introduced by the prospective increase in traffic occasioned by such substitution, renders any precise pre-determination impracticable. The enterprise and intelligence displayed by the management may often be of more importance than the cost of coal and other pre-determinable items. In America, the substitution of electricity for steam on the elevated roads in large cities has generally led to the most unexpected increase in traffic; the increase sometimes amounting to over 30 per cent. in the first year after such substitution.

One would be inclined to hazard the prediction, that while electricity will soon be widely employed as the motive power for the suburban and inter-urban service of main lines, the through trains will still be hauled by steam locomotives; and only on sections of the line near large cities and towns will a conducting system be provided.

Such a proposition is unattractive, owing to the lack of uniformity thereby entailed; and elaborate tentative work is now being carried on all over the world with a view to solving the problem of the economic use of electricity as the exclusive motive power on main line roads.

High-Speed Electric Traction

IT has been satisfactorily demonstrated by the experiments at Zossen in Germany, that the highest speeds desired can be obtained with comparatively little difficulty by electrically operated trains. Speeds of over 200 kilometers per hour were attained in these

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experiments. On existing railways, the general use of far lower speeds than this would, however, necessitate complete reconstruction of the track, at any rate at curves; for with the present standard gauge and general type of rolling stock, curves constructed for safe transit at high speeds would present danger at low speeds. Bridges, complex crossings, and especially tunnels, present grave difficulties in the matter of trolley or third-rail construction. Conservative estimates place the cost of the trolley or third-rail construction at some 30 per cent. of the entire cost of conversion to the electric system, where a pressure not exceeding 700 volts is used. With a view to the reduction of these costs, higher voltage alternating-current systems have been advocated, and are already employed to a limited extent. Up to a couple of years ago, the three-phase system appeared the most promising of these alternating-current methods: it was installed on the Valtellina Railway in Northern Italy; but the single-phase system is now generally believed to offer greater general advantages. While some large manufacturing companies exploit single-phase systems, employing single-phase motors on the cars, the Oerlikon Company advocates a single-phase system in which a locomotive carries a single-phase motor driving a continuous-current generator, from which the continuous-current traction motors are supplied. In virtue of the avoidance of rheostatic losses, the use of regenerative braking, and other features, this system appears to be very economical. Its introduction would disarrange present steam railway methods to a smaller extent than any other practicable system.

New York Central Railway

THE most important electrical undertaking now being carried out by a great railway is that of the New York Central Railway, in which all those sections of its various lines lying within a radius of fifty miles of New York City are being changed over to electrical operation. The steam trains at present enter the city through a series of tunnels, making the use of steam locomotives exceedingly objectionable. When electrified, the suburban service will be operated by so-called "multiple-unit" trains, each consisting of a few cars, the axles of some or all of which are driven by independent electric motors, all electromagnetically controlled from either end of the train. This distribution of the driving effort permits of quick acceleration with light trains. A frequent service of short trains best meets the needs of "commuters," as the suburban residents are called. The express trains will be hauled through this 50-mile radius electric zone, by the most powerful electric locomotives in the world. Each locomotive will weigh 85 tons, and will be able to haul a 400-ton train at a speed of 70 miles per hour.* This requires a capacity of over 2,000 horse-power. Beyond the electric zone these express trains will be hauled by steam locomotives. The first order for thirty of these 85-ton electric locomotives has already been placed; several hundred will ultimately be required for the contemplated service.

Inter-urban Roads

ONE should carefully distinguish between the introduction of electric operation on existing steam lines, and the operation of new lines. In the latter case, the use of electricity as a motive power would be attended with comparatively little difficulty. In America there are already in operation a great number of so-called "inter-urban roads" connecting cities from 25 to 200 miles apart. These are generally single-track roads, on which single cars of some 25 tons weight are operated at intervals of twenty minutes or more. They make stops every few miles, and run to an average schedule speed of some 25 miles per hour, including stops. The rolling stock is well-built and attractive, but the power plant and sub-stations are generally of a very crude description; this must necessarily be the case in such work, since otherwise the capital charges would preclude economic success. In nearly all these plants, the current is generated by three-phase dynamos (often driven by water-power) and supplied to the line at from 10,000 to 30,000 volts. At sub-stations the electrical energy is transformed to continuous current at about 600 volts by stationary transformers and rotary converters. The sub-stations are ten miles or so apart, and are often combined with stopping places. The switchboard attendant sometimes performs the combined duties of porter, signalman, etc., and rarely has more than the most superficial understanding of the electrical apparatus in his charge. To obviate the

* The electric locomotives which, for several years, have been hauling 2,500-ton freight trains through the tunnels of the Baltimore and Ohio Railway near Baltimore, weigh 96 tons each, and are the *heaviest* electric locomotives in the world. The capacity of these goods locomotives, however, is only about 1,200 h.p., their speed being far below that of passenger locomotives.

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expense of spare apparatus in the sub-stations, a portable sub-station is often provided, consisting of a car carrying a rotary converter and switchboard. If the rotary converter in a sub-station breaks down, this portable sub-station is despatched to the spot and connected in. Thus one set of spare plant serves for the whole line. Owing to the infrequency of the service, the sub-stations have an extremely varying load, and even at the power-house generator or generators, the load is continually fluctuating from a small percentage of rated load, up to from 50 per cent. to 100 per cent. overload. In spite of all these difficulties, such roads are generally remunerative investments, and provide such low fares and so good a service as to greatly interfere with the local traffic of the steam roads which they parallel. But the traffic which they divert from the steam roads is but a very small percentage of their total traffic; in other words, the facilities they offer so greatly stimulate intercourse between the towns connected, as to bring into existence a large passenger and goods traffic almost immediately upon the establishment of the service. The latest innovation on these roads is the establishment of a service of sleeping cars. These cars are transferred from road to road without disturbance to the passengers.

An Automatic Trolley Turning Device for Electric Tramcars

In the April number of Technics, a diagram was given showing the automatic method adopted by the London United Tramways Company for transferring the trolley from the "up" to the "down" line at their Shepherd's Bush terminus. This is operated by the conductor or pointsman pulling over the movable tongue

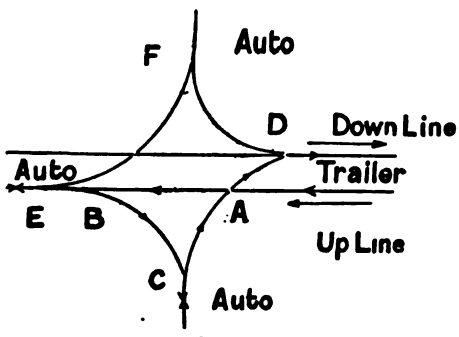

Fig. 2.

in the overhead frog to the required position, by means of wires. Though a saving is effected by this method, the employment of a man to pull the wire is of course a disadvantage; and Messrs. R. W. Blackwell & Co., Ltd., the well-known firm of electric traction engineers, have devised and carried out, at Doncaster and several other towns, an improved method whereby the services of a man are dispensed with altogether. This device has now been in successful use for some time. The general arrangement is as indicated in Fig. 2.

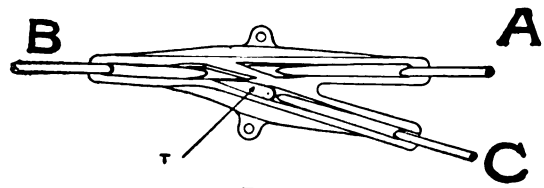

Fig. 3.

The car approaches on the "up" line in the direction shown, and the trolley passes over the crossing A, and then over the automatic frog B, pushing aside the spring-controlled tongue in it. The construction of this frog is shown in Fig. 3, which gives a view of the under side or running face. The tongue T is always kept on one side in the position shown, by the aid of a spring at the back. With this

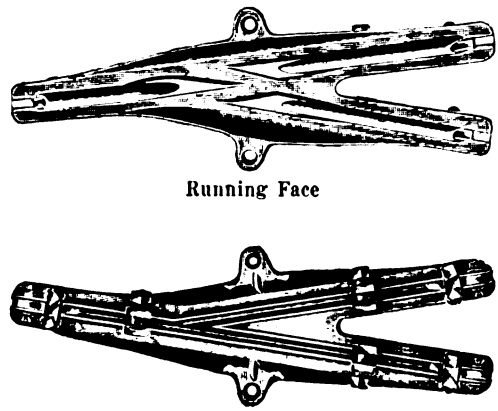

Fig. 4.

type of frog, a car can come either in the direction A B, or C B; in the former case the trolley wheel pushes aside the spring-controlled tongue, and in the latter, of course, runs over it. When the car comes in the reverse direction the only course open to the trolley is along B C.

In the arrangement considered here, when the trolley head has passed the automatic frog at B (Fig. 2), it is guided on its return towards C: at that point another automatic

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frog is placed, which only allows the trolley head, when once it has gone beyond it, to take the direction towards the crossing A on its return, following the direction of the arrow heads, until it joins the "down" line by aid of the trailing frog at D.

This latter frog, of which a view is given in Fig. 4. does not need to have a movable tongue, since all trolleys that pass over it go in the one direction, indicated by the arrow.

The arrangement can be duplicated as shown in the upper part of Fig. 2, by putting another automatic trailing frog at E, and also one at F; the trolley wire from F is then either connected to a three-way trailing frog at D, or to another two-way frog, placed in front of D, whichever is most convenient.

In addition to the saving of a man's time in turning the trolley arm round at the end of the journey, and the trouble on a dark night of getting the trolley head on to the overhead conductor again, a method like this adds greatly to the comfort of passengers who are getting into the car, as they are not left in darkness until a communication is established with the trolley wire.

THE most efficient use of floor space in London, or indeed any large town, is a matter of considerable importance to the power user; as the greater the number of money-making machines installed in a given space, the greater will be the output and return for a given capital cost. The recent extended use of electric power in factories may in a measure be attributed to recognition of this fact; but at the same time, the enormous difference in floor space taken up, power for power, by oil and gas engines and electric motors is certainly not so generally appreciated as it should be. Fig. 5 puts the matter in a very forcible light. It is constructed from the

Power for Workshops and Floor Space

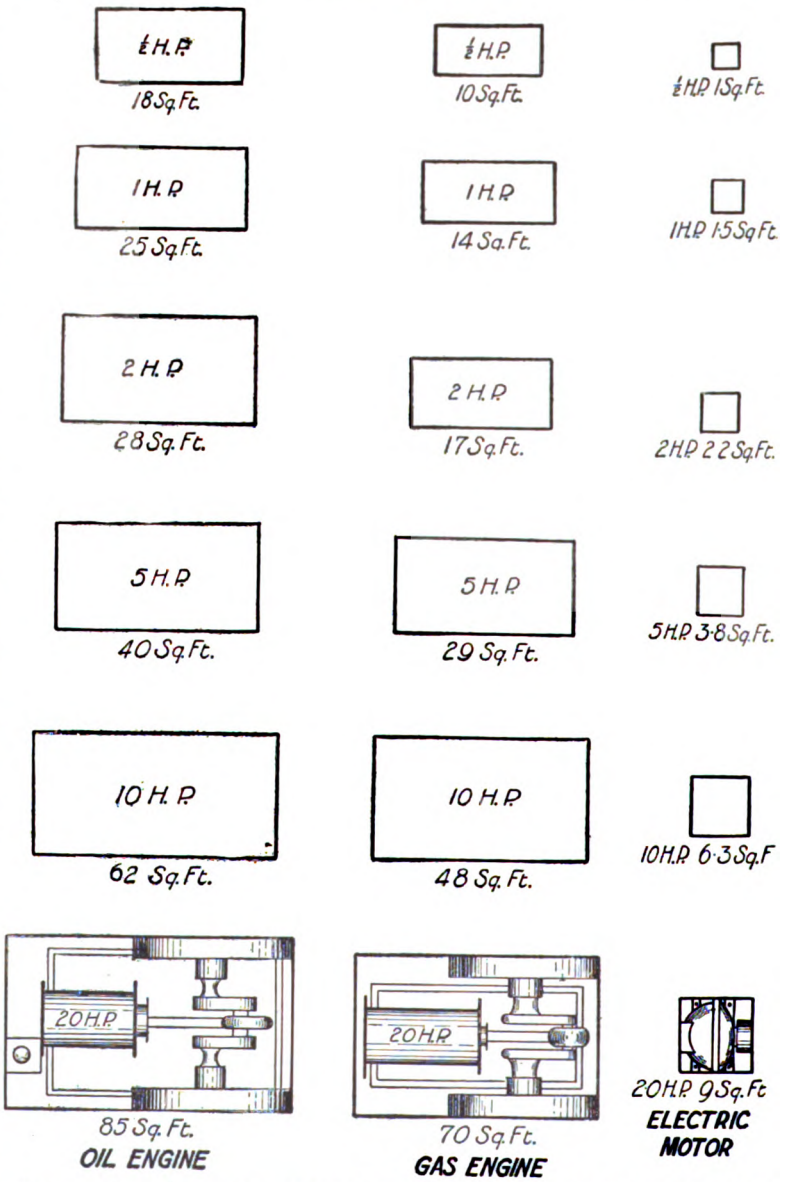

FIG. 5.—TO SHOW THE RELATIVE FLOOR SPACES REQUIRED FOR OIL AND GAS ENGINES, AND ELECTRIC MOTORS.

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mean of the overall dimensions of various makes of engines and motors, the latter being of the semi-enclosed type. Of course, speed is the secret of the great difference, it being impossible, with the exception of the petrol motor, to efficiently run any reciprocating engine at a speed approaching that of the electric motor.—It may not be looking too far ahead to anticipate the petrol engine as a dangerous competitor to the electric motor, its high speed placing it under much the same conditions as regards cheapness and economy of floor space.

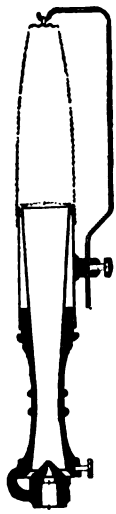

FIG. 6.
SECTION OF KEITH BURNER.

Keith-Blackman Burner and Mantle

IN order to obtain the best luminous efficiency from an incandescent gas mantle, the flame used to heat the mantle should be more nearly akin to a blowpipe than to an ordinary Bunsen flame. This result is attained in various ways by different systems; in the Keith-Blackman system the pressure of the gas is raised about eight inches above the atmospheric pressure, instead of being used, as supplied by the gas companies, at a pressure of about three inches above the atmospheric. Fig. 6 represents a section of the Keith burner. The nipple from which the gas escapes into the Bunsen tube is carefully designed for the pressure used; by screwing the burner in one direction or the opposite, the size of the air inlet can be adjusted to a nicety. Before the mantle is placed on the burner, the air inlet should be entirely closed, and the flame lighted over the wire gauze cap B (Fig. 7), which covers the orifice of the tube C. The air inlet should then be gradually opened till a conical non-luminous flame is produced, with a number of bright blue flames evenly distributed over the gauze. The mantle is then placed in position, and a fraction of a turn one way or the other serves to adjust for the most efficient light. When properly adjusted the burner requires five parts of air to each one of gas.

Dust is the great enemy of the incandescent mantle: since deposition of dust on it cannot be avoided, the next best thing is to provide means for its ready removal. From Fig. 7 it will be seen how the mantle, attached to the tube A, can be removed; dust can then be cautiously blown off. The support for the mantle can be adjusted so that the whole of the mantle is equally luminous. The Keith flame is "solid," instead of possessing the form of a hollow cylinder, as in other burners: this gives the advantage that the mantle is more uniformly heated, the heat from the inner parts of the flame serving to keep the top of the mantle at the same temperature as the lower parts.

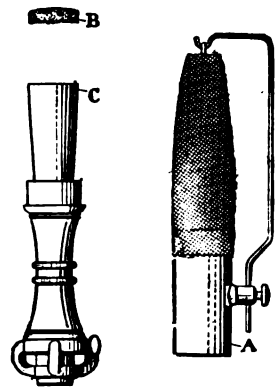

FIG. 7.
DETAILS OF KEITH BURNER.

THE compressing apparatus used in the Keith-Blackman system is represented in section and end elevation in Fig. 8. The work of compressing is performed by a small water motor M, which alternately raises and lowers the bell B. A set of four valves (not shown in the diagram) are so arranged that gas from the supply mains can be sucked into the bell B, or into the space between B and the en-

Keith-Blackman Compressor

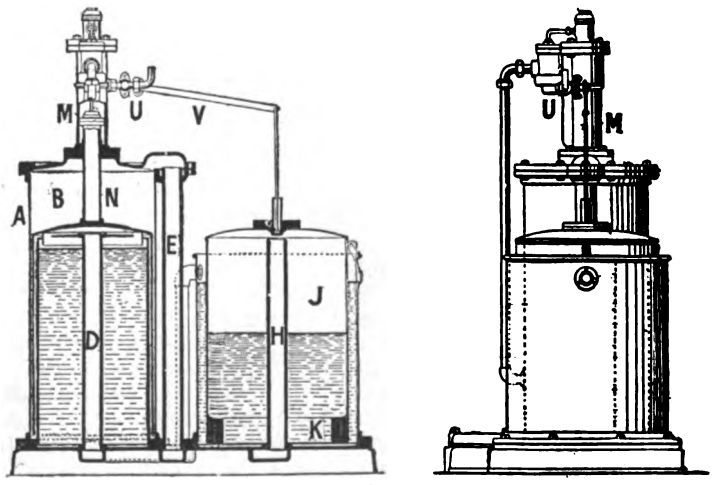

FIG. 8.—KEITH COMPRESSOR.

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closing vessel A; while it is expelled from either of these regions into the gasometer J. Thus, as the bell B is raised by the pump, gas in the space above it is forced into J, by way of the pipe E; at the same time gas from the supply mains is sucked into the space above the water within B, by way of the pipe D. As the bell B descends, the gas within it is forced, by way of the pipe D and one of the valves, into J; while gas from the supply mains is drawn into the space above B. The water within the vessel A serves as an efficient and frictionless seal between the spaces inside and outside B respectively. The gasometer bell J is weighted at K, so that the pressure always amounts to eight inches of water above the atmospheric pressure. As the bell rises, it acts on the lever V, so as to gradually close the valve U, controlling the water supply to the motor M; when J is at its greatest height, the valve U is entirely closed, and the water motor ceases to act.

THE burners are made in four sizes, of which details are given in the following table.

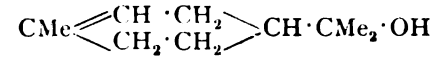
Candle-Power.	Gas Consumption, in cubic feet, per hour.
150	5
225	7·5
300	10
1,000	33

Efficiency and Cost

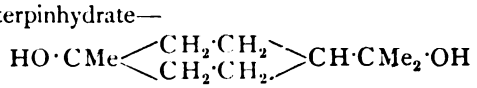
These values are somewhat less favourable than might be quoted, an efficiency of 36 candle-power for each cubic foot of gas consumed per hour having frequently been obtained. In lighting large buildings, it is generally agreed that the best results may be obtained by the use of numerous small units, so as to avoid strongly defined shadows. In workshops, a light of from 0·75 to 1·0 candle-power per superficial foot meets with all requirements, the latter figure being sufficient for cases where delicate work is being carried out.

Synthetical Terpenes

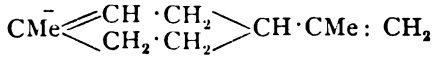
THE final stage in the synthesis of camphor, which was recently accomplished by Komppa, lost much of its immediate interest by reason of the fact that the stages reaching from the elements up to apocamphoric acid, and from camphoric acid to camphor, had already been worked out; and nothing was required to complete the synthesis but the introduction of the methyl group, which is present in camphoric acid, but absent in apocamphoric acid. The recent researches of Professor Perkin, of Manchester, on the other hand, have resulted in the complete and immediate synthesis of three important members of this group of compounds, namely, terpineol—



terpinhydrate—



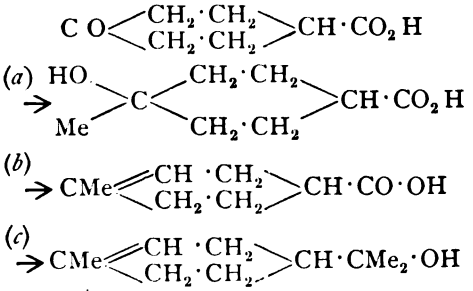
and dipentene—



All these are readily produced from ordinary turpentine; dipentene is an important constituent both of Russian and of Swedish turpentine. The synthesis of such compounds is one of the most difficult tasks of organic chemistry, and its successful accomplishment is a splendid tribute to the skill and perseverance of the Manchester School of Organic Chemistry.

Metallic Magnesium as a Synthetic Agent

THIS series of syntheses was accomplished with the help of metallic magnesium, a synthetical agent which was introduced by Grignard only four years ago, but has already proved of great value in an extraordinary number of different instances. In the case under consideration it was used to bring about the two critical operations of the synthesis, and as the substances produced are of fundamental importance in organic chemistry, it may be permitted to record the steps leading from ketohexahydrobenzoic acid to terpineol, as illustrated by the formulæ of the intermediate compounds:—



The stages marked (*a*) and (*c*) were effected by means of metallic magnesium, and in this way the difficult task of introducing three methyl groups into the molecule was accomplished.

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THE RADIATION AND EMANATION OF RADIUM.

By E. RUTHERFORD, M.A., D.Sc., F.R.S.,
Macdonald Professor of Physics, McGill University, Montreal.

SCARCELY more than seven years have elapsed since Becquerel discovered that uranium possesses the property of spontaneously emitting radiations, capable of passing through substances opaque to light, of acting on a photographic plate, and of discharging electrified bodies. Nevertheless our knowledge of the subject has grown with surprising rapidity, and a very large amount of information has now been collected, not only concerning the radiations from the radio-active bodies, but also of the complicated processes occurring in them. A theory has also been advanced which serves to connect in an intelligible manner the remarkable series of phenomena observed.

Soon after Becquerel's discovery of the radio-active properties of uranium, the rare element thorium was found to be radio-active. An examination of the mineral pitchblende has revealed the presence of a series of new radio-active bodies, which possess the property of radio-activity to a very intense degree compared with uranium and thorium. Of these bodies, the substance *actinium*, discovered by Debierne, will probably prove to be a new element of activity comparable with that of radium; while the radio-active elements present in the *polonium*, discovered by Mme. Curie, and the *radio-tellurium*, discovered by Marckwald, have not yet been chemically isolated. The substance *radium*, discovered in 1898 by M. and Mme. Curie in pitchblende, has attracted the greatest amount of attention, partly on account of the fact that it has been found to be a new element with a definite spectrum and atomic weight; but chiefly on account of its surprising radio-active properties: for its radiations are nearly two million times as intense as those emitted from an equal weight of uranium.

Much of our present knowledge of radio-activity has been derived from a study of the comparatively feeble radio-active bodies, uranium and thorium. The radio-active properties of thorium are qualitatively similar to those of radium, but differ very widely in intensity. In this article, for brevity, the properties of radium alone will be considered, although the explanation advanced for radium in many cases applies also to the other radio-active bodies.

The characteristic radiations from radium are invisible to the eye, but are, in part, transformed into light when they fall on certain fluorescent substances. An ordinary X-ray screen of barium platino-cyanide is rendered luminous in a dark room when the rays from radium fall upon it. The mineral *willemite* (zinc silicate) lights up brightly under the rays from a few milligrams of radium bromide; it appears quite translucent, emitting light of a beautiful greenish colour. Another mineral, *kunzite*, exhibits a beautiful rose colouration under the rays, but the intensity is not so marked as in the case of willemite or crystals of the platino-cyanides.

The radiations from radium are very complex in character, and comprise three kinds of rays, called the α, β and γ rays. The greater part of the rays emitted bear no resemblance to ordinary light waves, but consist of flights of material particles projected with enormous velocity. The nature of the β rays was first determined, on account of the ease with which they are deflected by a magnet. If a small quantity of radium bromide is placed at the base of a small lead cylinder, the cone of rays issuing from the open end produces a luminous patch on a willemite or X-ray screen brought near it. The luminosity observed is mainly due to the β rays. On bringing up a magnet near the radium, the light patch is observed to be deflected and also to be greatly broadened. By reversal of the magnet, the direction of movement is reversed. The broadening of the cone of rays in a magnetic field shows that the rays emitted are complex in character, some of them being more readily deflected by a magnetic field than others. In a similar way, it has been found that the rays are deflected in passing between two parallel plates kept charged to a high difference of potential by an electric machine. In these and other respects, the β rays are identical with the rays which are shot off from the cathode when a strong electric discharge is passed through a vacuum tube.

By measuring the amount of deflection of the cathode rays, in passing through both a magnetic and electric field of known strength,

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J. J. Thomson has shown that they consist of a flight of particles, carrying negative charges of electricity, and projected with a velocity of about 50,000 miles a second. The particle shot off from the cathode is the smallest body known to science, for apparently its mass is only about $\frac{1}{1000}$ of that of the hydrogen atom. The β particle shot out from radium is identical in size with the cathode ray particle, but is projected with a much greater average speed. Kaufmann has shown that some of the particles possess an initial velocity of over 170,000 miles per second, *i.e.*, a velocity very nearly equal to that of light.

The γ rays from radium are of an extraordinarily penetrating character, for their presence can readily be detected through several inches of lead or a foot of iron. They are not deflected by a magnetic or electric field, and there is now little doubt that they are a type of very penetrating Röntgen rays. According to the views of Stokes and J. J. Thomson, Röntgen rays are very short transverse waves or pulses in the ether, which are set up when the cathode ray particle is suddenly stopped by striking an obstacle. It is to be expected that Röntgen rays should be set up at the sudden *starting* as well as at the sudden stopping of a charged particle, and the present evidence points to the conclusion that the γ rays arise at the moment of the expulsion of the β particle from the radium atom. Thus, unlike the β rays, the γ rays are not corpuscular in character, but are more akin to very short light waves.

The α rays have very slight penetrating power and are absorbed in their passage through a few centimeters of air or by a sheet of paper. They were for a long time thought to be incapable of deflection by a magnetic or electric field; but in 1902, the writer found that they could be bent from their path by the application of a very intense magnetic or electric field. The direction of deflection was, however, opposite to that observed for the β rays, which showed that the α rays carried with them, not a negative, but a positive charge of electricity. By observing the amount of bending of the rays in passing through a magnetic and an electric field of known strengths, it was deduced that the α particles are projected with a velocity of about 20,000 miles a second, and have a mass about twice that of the hydrogen atom. If the α particles consist of any known kind of matter, these measurements pointed to the conclusion that they were either hydrogen or helium atoms, for next to hydrogen, helium has the lightest atom known to science. The significance of this result is seen in the light of the production of helium from radium, which will be considered later.

The fundamental phenomenon of radioactivity consists in this continuous and spontaneous expulsion from radium of heavy particles of matter, atomic in size, with enormous velocity. Each particle has a velocity about 40,000 times as great as a rifle bullet, so that its energy of motion is enormous compared with the mass of the body in motion.

The rays from radium are very similar to those produced when a strong electric discharge is sent through a vacuum tube. The β rays are like the cathode rays, the γ rays are similar to the Röntgen rays, while the α rays are very analogous to the "canal" rays discovered by Goldstein. In order to produce these rays in a vacuum tube, a large expenditure of electric energy is required. Radium, on the other hand, gives them out spontaneously, without, so far as is known, the action of any external exciting cause.

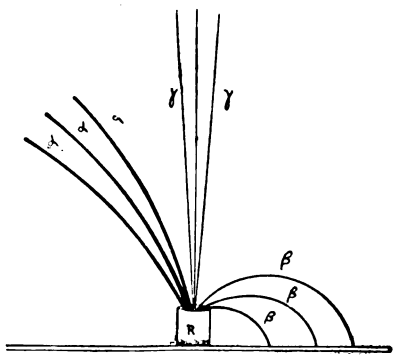

FIG. 1.

The effect of a magnetic field in separating out the rays of radium is shown diagrammatically in Fig. 1. The radium R is placed in a small lead vessel, and the α, β and γ rays are projected as a cone of rays from the opening. On applying a magnetic field at right angles to the plane of the paper, and in a direction downwards through the paper, the β rays are bent to the right, the α rays to the left, while the γ rays are not bent at all. The amount of bending of the α, compared with the β rays, is very much exaggerated in the figure.

The comparative size, velocity and energy of motion of the α and β particles is shown graphically in Fig. 2.

The energy of motion of the α particle is much greater than that of the β particle.

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There is, in addition, evidence to show that four α particles are projected for every β particle, so that nearly all the energy emitted from radium, in the form of rays, is carried off by the α particles. Not only are the α particles of more importance from the point of view of emission of energy, but they also play a far more important part in the complicated processes which occur in the radium atom. It can be calculated that every gram

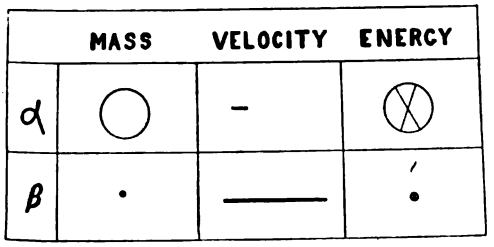

FIG. 2.
The velocity is represented by the length of a line and the mass and energy by spheres.

of radium projects about one hundred thousand million α particles per second, and yet there is such an enormous number of atoms in a gram of matter that the process could continue for years before an appreciable proportion of the matter had been fired away.

The rate of expulsion of the α or β particles is not appreciably influenced by any physical or chemical agency under our control. At the temperature of liquid air, it proceeds at the same rate as at a red heat.

The continuous expulsion of α particles from radium is very well illustrated by a beautiful experiment devised by Sir William Crookes. If a trace of radium is brought near to a zinc sulphide screen, the surface of the screen is rendered luminous by the α rays. On examining the screen with a magnifying glass, the luminosity is found to lack uniformity, consisting of a multitude of sparks of light coming and going with great rapidity. The action brings vividly before the observer the idea that the screen is subjected to an intense bombardment, the impact of every projectile as it strikes the target being marked by a flash of light. The massive α particles have such an enormous energy of motion, compared with their size, that they produce, at impact, an alteration in the crystals of zinc sulphide—probably a cleavage—which is accompanied by a flash of light.

The most important property possessed by the radiations from the radio-active bodies is that of discharging electrified bodies. This property has been utilised as a means of accurate measurement of the radiations, and is by far the most delicate method of detecting the property of radio-activity in bodies. If radium exists in a gram of inactive matter, only to the extent of *one part in ten thousand million*, its presence can readily be detected by its power of discharging a gold leaf electroscope. This discharging action of the rays is due to the production of positively and negatively charged particles, or ions, as they are termed, in the electrically neutral gas through which the radiations pass. The α and β particles have such a large energy of motion that they produce ions by collision with the gas molecules in their path: each projected particle is capable of producing many thousands of ions before its energy is dissipated. These ions travel in the electric field and cause the loss of charge observed.

If a trace of radium bromide is placed on a plate A (see Fig. 3) near a plate B, connected metallically with a charged gold leaf electroscope E, the charge is very rapidly dissipated, and the leaves L rapidly collapse. Most of this discharging action is due to the α rays. If a sheet of paper is placed over the radium, the α rays are almost completely intercepted by it, and the discharging action is then due to the β and γ rays. If the radium is completely covered with a lead screen about 5 millimeters thick, the β rays are almost all stopped, and the discharge in the electroscope is thus caused by the action of the γ rays alone. Speaking generally, the

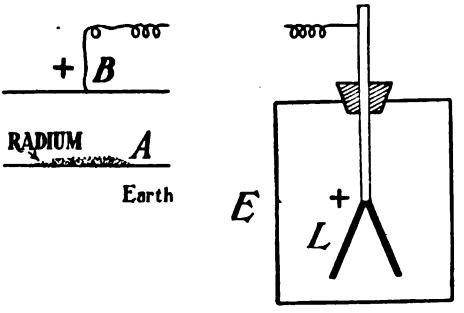

FIG. 3.

α rays are far more effective in causing discharge, and producing luminosity in bodies, than the more penetrating β and γ rays. On the other hand, the β rays are the most active in darkening a photographic plate.

Curie and Laborde recently showed that radium possesses the striking property of continuously keeping itself at a temperature of 4° or 5° F. above the surrounding air. This shows that radium, in addition to its

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radiations, continuously emits energy in the form of heat. The amount of heat from 1 gram of radium corresponds to about 100 gram-calories per hour. A pound of radium would emit per year about as much heat as is given out by the combustion of one hundred pounds of coal. This is a very remarkable result, for at the end of a year the radium shows no apparent sign of alteration, and still continues to give out heat at an undiminished rate. The rate of heat emission has been shown, by Curie and Dewar, to be unaltered when the radium is kept at the temperature of liquid hydrogen.

This emission of heat is, in reality, directly connected with the radio-activity of radium, and is not an independent phenomenon. There is little doubt that the heat emission is a direct consequence of the continuous expulsion of α particles from the radium. The α particles are readily absorbed in their passage through matter; and in a pellet of radium, only a small percentage of the total number emitted are able to escape into the surrounding gas. The rest are absorbed in the mass of the radium itself. The radium is thus subjected to an intense and continuous bombardment by the α particles projected from its own mass. Just as a target is heated by the impact of bullets upon it, so the radium becomes hot in consequence of its self-bombardment. A part also of the heat emitted probably results from the explosion in the atom, which results in the ejection of the α particle.

Not content with emitting three kinds of rays and continuously giving off heat at a rapid rate, radium also produces from itself a radio-active "emanation" or gas. This emanation is produced in minute quantity; but compared with the amount of matter, is an extraordinarily powerful radiator of energy. This property of giving off an emanation was first observed by the writer in the radio-active element thorium. If a slow current of air is passed through a tube T (Fig. 4) containing some powdered thorium oxide, or still better, thorium hydroxide; and is then passed through several yards of tubing opening into the electroscope E, the gold leaves of the electroscope are observed to rapidly collapse. The emanation, mixed with the air, is conveyed into the electroscope, and the radiation from it ionises the gas and causes the collapse of the leaves. If the current of air is stopped, the rate of discharge

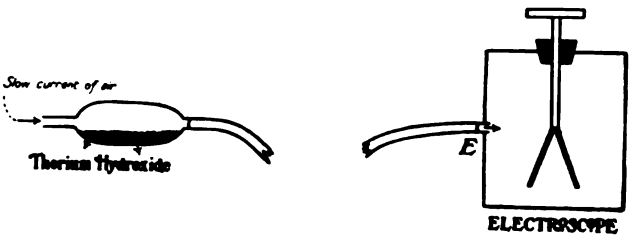

FIG. 4.

rapidly decreases with the time, falling to half value in an interval of one minute. If a radium solution is substituted for the thorium, a similar action is observed; but on account of the enormous activity of radium, the effects are far more intense. The emanation obtained from *one millionth of a gram* of radium bromide causes the leaves to collapse in a few seconds, while the emanation from *one ten thousand millionth of a gram* is readily measurable. This property of radium, of giving off an emanation, affords the most delicate and certain method of detection and estimation of minute quantities of radium. The emanation of thorium is very readily distinguished from that of radium, on account of the slow loss of activity of the latter. The radiating power of the emanation of radium falls to half value in four days, and is still appreciable after it has been stored up in a closed vessel for a month.

The emanations of thorium and radium have been the subject of a large amount of investigation. They have been shown to diffuse through air like heavy gases, and to be unacted on by any known chemical reagents. Mr. Soddy and the writer found that the emanations of thorium and radium could be condensed, like gases, by the action of extreme cold. The thorium emanation condenses at $-120°$ C., and the radium emanation at $-150°$ C. With a large amount of radium emanation, the process of condensation can be followed by the eye. A simple experiment for this purpose is shown in Fig. 5. A quantity of emanation is collected in the small gasometer by bubbling air through a radium solution. The emanation, mixed with air, is then passed through a glass U tube, immersed in liquid air contained in a Dewar flask. In order to show the presence of the emanation, the U tube is partly filled with small pieces of willemite. As the emanation is slowly carried into the U tube, it condenses at the point of the tube just below the surface of the liquid air. The radiations from the condensed emanation render the willemite

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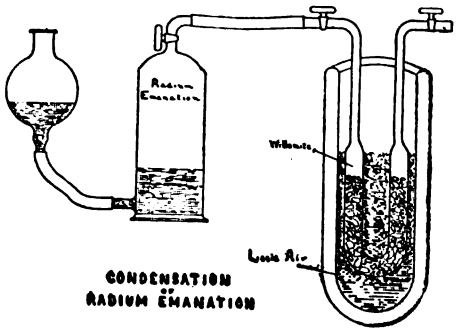

FIG. 5.

luminous; and, with a considerable quantity of emanation, the luminosity is very brilliant. With a very slow current of air, the luminosity is concentrated at the portion of the U tube where the air enters, while the rest of the tube is not luminous at all. On closing the ends of the tube and removing it from the liquid air, the emanation volatilises as soon as the temperature rises above −150° C., and the whole tube becomes luminous. The light from the tube slowly diminishes, as the enclosed emanation loses its activity, but is still appreciable after a month's interval.

If the emanation, after being allowed to remain in the U tube for several hours, is blown out by a current of air, the luminosity of the willemite does not at once disappear, but continues for several hours. This continued luminosity is due to a remarkable property possessed by the emanation of *manufacturing from itself a new kind of radio-active matter which is not gaseous, but behaves like a solid*, and is deposited on the surface of bodies. A body which has been exposed some time in the presence of the emanation, behaves as if it were covered with an invisible film of intensely radio-active matter. This deposit is soluble in acids, is driven off at a white heat, and generally acts like a substance with definite chemical properties. The deposited matter continues to radiate for several hours. This power of "exciting" or "inducing" activity in neighbouring bodies is possessed by the emanations of both thorium and radium. The excited activity produced by the thorium lasts much longer than that produced by the radium emanation, and is appreciable several days after the emanation has been removed.

If the tube in which the radium emanation is stored is filled with layers of different substances which are rendered luminous by the rays, the differences in colour and intensity of the luminosity can be very clearly seen. Willemite shines with a beautiful green colour, and kunzite with a dark red colour. Zinc sulphide shows a white luminosity. Crystals of barium platino-cyanide are at first as luminous as willemite; but the colour and luminosity of the crystals rapidly change, due to a chemical action of the rays upon them. The luminosity of willemite and zinc sulphide is mostly due to the α rays, while kunzite is more sensitive to the β and γ rays.

A tube containing the radium emanation has temporarily all the properties of radium. It gives out β and γ rays, and also emits heat at a rapid rate. The emanation, when collected in a concentrated form, is luminous in the dark and causes glass to phosphoresce. It rapidly blackens the walls of the glass tube containing it, and is able to produce marked chemical action in some substances. If collected over water, it manufactures hydrogen and oxygen at a rapid rate. All these effects are produced by an extraordinarily small amount of the emanation. Sir William Ramsay and Mr. Soddy have recently succeeded in isolating the emanation from radium, and in determining its volume. They calculated that one gram of radium contains about one cubic millimeter of the emanation, when measured at atmospheric pressure and temperature. The emanation has all the ordinary properties of a gas. It has a definite spectrum, but it differs from all other gases, inasmuch as its volume diminishes with time: it is not permanent, but is continuously changing into a solid substance, which is deposited on the walls of the containing vessel. But the most remarkable feature of the emanation is its enormous power of radiating compared with its weight. Dr. Barnes and the writer recently showed that three-quarters of the total heating effect of radium is due to the small amount of emanation stored up in it. The emanation was removed from the radium by heating it, and then collected by condensation in a small glass tube immersed in liquid air. The tube containing the emanation glowed in the dark and gave off heat at a rapid rate, while the radium from which the emanation was separated lost three parts of its heating effect. The emanation lost its heating effect at the same rate as it loses its activity, *i.e.*, the heating effect diminished to half value in four days, and had nearly disappeared in the course of a month. The radium at the same time spontaneously regained its power of heat emission, and after a month's interval gave out heat at the same rate as before the experiment.

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Not only does the emanation itself give out heat, but the matter which is deposited from it on the walls of the vessel does so also. The heating effect was found to depend upon the emission of α particles, and is directly connected with the radio-activity. The greater portion of the heating effect of the emanation is due to the continuous bombardment of the walls of the tube and the contained gas by the α particles, which are thrown off by the emanation, and the other substances which are produced from it. If one cubic inch of the emanation were collected, the heat energy from it would be sufficient to melt down the walls of the glass tube containing it. It can readily be deduced that, weight for weight, the emanation emits about a million times more energy than that produced in the most violent chemical reaction. A pound weight of the emanation, immediately after its separation, would give out energy at a rate of about 10,000 horse-power. The rate of emission of energy would decrease to half value in four days, and would be appreciable after a month's interval; but the emanation, during the time its activity lasts, would give out an amount of energy equivalent to an engine working at 10,000 horse-power for six days. If it should ever be possible to obtain a large quantity of this emanation and to utilise its energy, a few pounds of it would suffice to provide enough power to drive a liner across the Atlantic. As it would probably require about fifty tons of radium to produce one pound of the emanation, the outlook for the utilisation of the emanation as a source of power is not at present very promising.

(To be continued.)

THE PRESENT STATE OF THE ART OF LIGHTING.

IN a paper recently presented to the Association of German Engineers, W. Wedding compares the different systems of lighting from the point of view of the luminous intensity, the cost, the evolution of heat, the utilisation of energy, etc. As regards the luminous intensity, an ordinary petroleum lamp with a 14-line burner will produce 14·8, an incandescent alcohol lamp 65·3, and an incandescent gas lamp 73·8 normal candles. Auer light appears to be the most economical with respect to the cost per candle-power. "Intensive gas" burners, as lately designed, produce enormous amounts of light; Lucas light, characterised by a prolonged funnel and an augmented draught, produces 481 candles, whereas compressed gas lamps produce 303, and millennium light the enormous amount of 1,500 candles. As regards electric lamps, small carbon filament incandescent lamps will give 18·3, and larger lamps 33·8 candles, while the figure corresponding to osmium lamps is 42·3, and to Nernst lamps 184 candles, measurements being made in a horizontal direction.

All these different lighting systems utilise rather imperfectly the energy stored up in the fuel; in this connection it may be mentioned that the 30½ millions of normal candles of light as produced by way of electricity in Berlin (*i.e.* 500,000 incandescent lamps of 25 candles, and 18,000 arc lamps of 1,000 candles each) would, if the energy stored up in the coal were entirely utilised, require only $\frac{1}{400}$-h.p.; *viz.*, a power that could be exerted by a little child. The production of light from gas is equally inefficient. Incandescent alcohol light and flame arcs show the most advantageous utilisation of fuel. As to incandescent electric light, osmium light is remarkable for its constancy and for the fact that the filaments break so soon as the lamp has lost one-fifth of its initial luminous power. Nernst lamps, which have for some time past been extensively used, will stand, on an average, 700 to 800 burning hours. As to electric arcs, Bremer light requires only one-third of the energy necessary for an ordinary arc lamp. Enclosed arc lamps represent another improved type. Mr. Wedding points out the importance which a uniform distribution of light would have for hygienical reasons. A novel luminescent lamp, on the Geisler tube principle, invented by the author, yields 200 candles.

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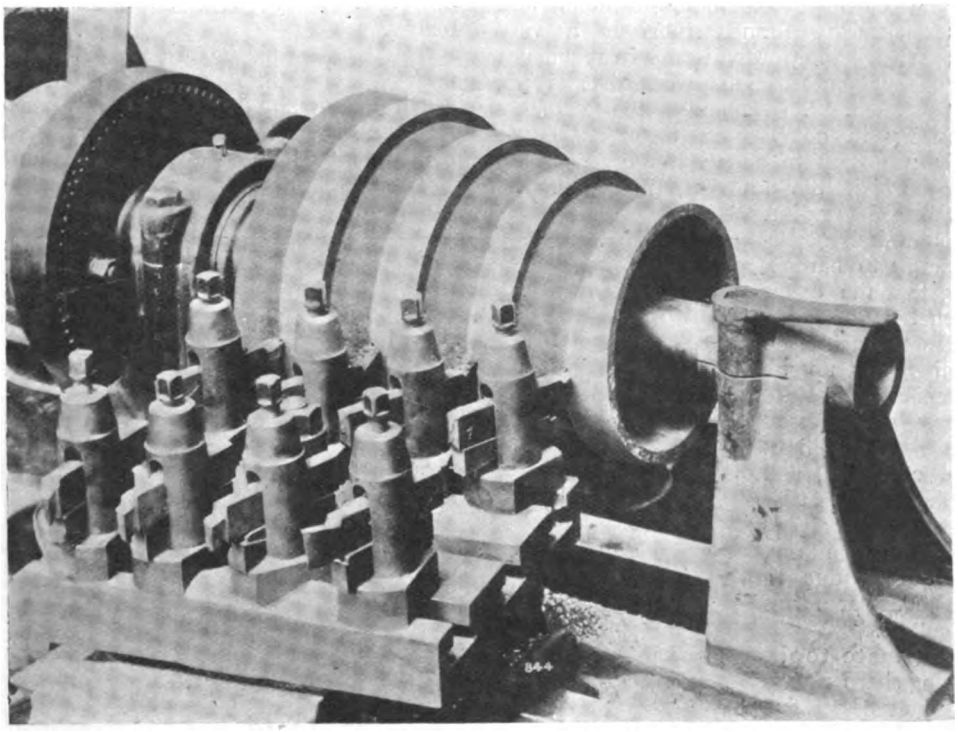
HIGH-SPEED TOOL STEEL.

Its Manufacture and Use.

PART II.

By J. M. GLEDHILL, of Messrs. Sir W. G. Armstrong, Whitworth & Company, Limited.



TURNING CONE PULLEYS WITH "A.W." STEEL.

This photograph was taken while the lathe was cutting at a speed equal to 120 feet per minute on the big step of the cone pulley.

AFTER the steel has been cast, it is passed on to a department known as the tilting-shop. The ingots are here reheated in accordance with their different compositions and then "cogged" or hammered.

Fig. 6 shows the heavy forging hammer, used for cogging ingots to the required shapes and sizes. These are then stacked and allowed to cool, after which a further examination is made, so that any defects that may exist can be detected before passing on to the smaller hammers for tilting and finishing. The very heavy sections for large milling cutters, shear blades, etc., are, however, finished under the large hammers.

We now pass to the annealing process, a very important branch of the business, especially to the users of tool steel. The very special brands of tool steel must not only be of the highest quality, but must be in such a state that they can be readily machined at the lowest possible cost to the many designs required for milling tools, boring tools, reamers, taps, dies, etc., and tools for delicate and very fine work. Another point of importance is the necessity of eliminating internal strains which are set up in hammering, rolling and finishing. The annealing brings the steel to a uniform and regular condition; so that when the steel is heated for hardening, equal expansion is obtained, also equal contraction when

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cooled in the air blast, or dipped in water or other quenching liquids used for hardening. Further, the tenacity and life of the steel is considerably increased by the annealing process. This quality of tenacity is especially requisite in tools that encounter sudden shocks in the course of their work, such as slotting tools, or turning tools on work where the cut is intermittent, and where corners require turning off.

The cracking of milling cutters and other specially formed tools is a very expensive matter, owing to the great amount of labour and machine work that is put upon them. To minimise this cracking tendency in complicated tools, it is not only necessary to anneal the bar of steel, from which the tools are made, in the hammered state; but it is desirable, preparatory to hardening, that the cutter itself be re-annealed so as to enable the strains set up by machining to release themselves and leave the metal in a normal condition, and further to minimise the evil effects caused by expansion and contraction due to the irregular forms of cutters.

Intricate tools, having sharp square bottom recesses, fine edges, or delicate projections, in which unequal expansion and contraction are liable to operate suddenly, are specially assisted by this second annealing. To demonstrate the effect of annealing, three samples have been taken from a steel bar, one being annealed and the other not. Also a test of "A.W." steel, annealed. On being submitted to a mechanical test they gave the following results, which speak for themselves :—

	No. O_2. Not Annealed.	No. O_2. Annealed.	"A.W." Annealed.
Yielding . .	30 tons	27 tons	—
Breaking . .	66·8 tons	42·5 tons	48·8 tons
Elongation . .	10·5%	24·5%	20·5%
Reduction of area	17%	40%	22%

Fig. 7 represents the emptying of a furnace of "A.W." annealed twist drill and cutter-blanks.

The bars or pieces are then "pickled," that is, dipped into a special solution, by which process any defects, such as seams or cracks, are rendered visible; afterwards the bars are put aside for further examination.

The bars and pieces are next transferred to

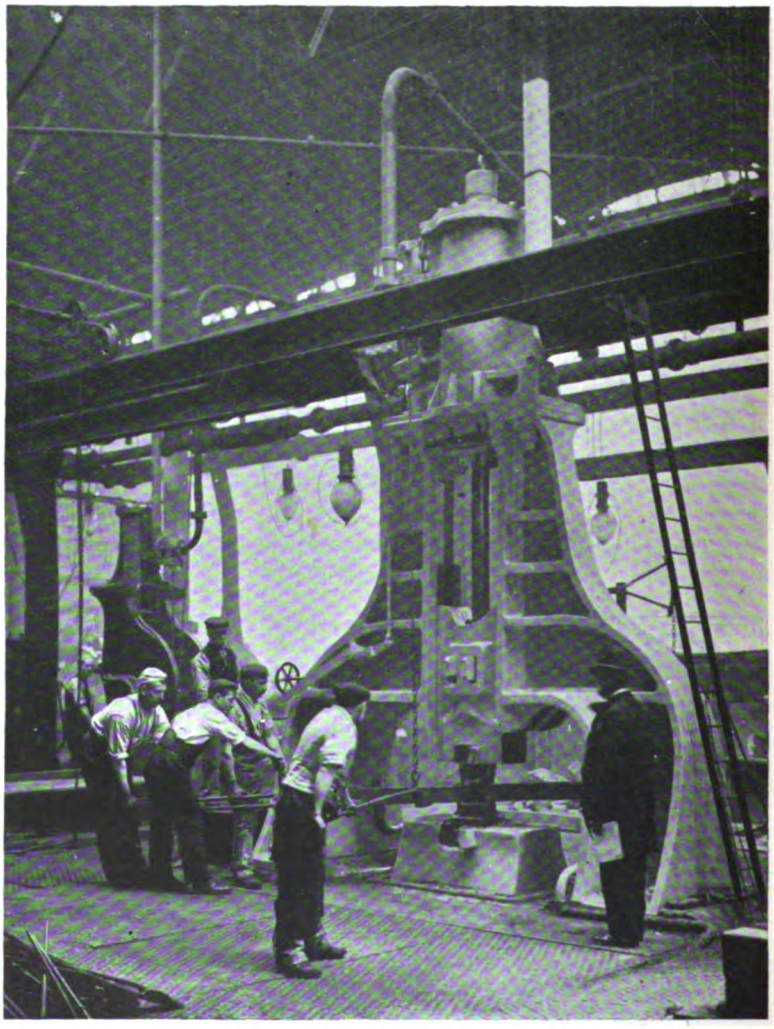

FIG. 6.—COGGING HAMMER

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the warehouse for final examination. Each bar is looked over separately to ensure that it is thoroughly sound and correct to size. A fracture is also taken from each end and minutely examined to detect if there are defects of any kind due to wrong working or treatment. Each bar is then stamped and labelled with name and trade mark, together with distinctive information to denote the quality and temper, and the special class of work for which the steel is suitable. The bars are then stacked in their respective places ready for bundling, packing, and delivery.

It might, perhaps, be advisable at this stage to refer to the methods of forging and hardening tools made from the "A.W." steel. Having obtained the bar, it is necessary to cut off the required lengths; and this must be done at a forging heat. The lengths must not be broken off cold, as this tends to cause cracks in the bars. For forging, the steel should be placed in the fire, and slowly but thoroughly heated, care being taken that the heating penetrates to the centre of the bar; it is then forged at a bright red heat. Whilst forging, the bar should not be allowed to get lower than a good red. After the tool is forged, it should be laid down in a dry place and allowed to cool slowly. To harden the tool, the nose only must be fairly rapidly raised to a white melting heat and then cooled with an air blast. If, during this heating, the point of the nose becomes fused or melted, no harm whatever has been done.

After grinding, which should be done on a wet stone, the tool is ready for use.

Another method which may be described of preparing the tools is as follows:—

Forge the tool as before, and when cold roughly grind to shape on a dry stone or dry emery wheel. The tool then requires heating to a white heat, just short of melting, and cooling in the air blast. This method also lends itself for cooling the tools in oil; before which the temperature has to be lowered from the white heat to a good red heat (about 1,600° F.) either by the air blast or in the open, and the tool then quenched out in oil. Tools hardened by the latter method are specially good where the retention of a sharp edge is a desideratum, as in finishing tools, capstan and automatic lathe tools, brass workers' tools, etc.

Referring to the question of grinding the tools, nothing has yet been found to be so good for air-hardening steels as the wet sandstone, the tools being ground by hand thereon; but where it is desired to use emery wheels, users are recommended to

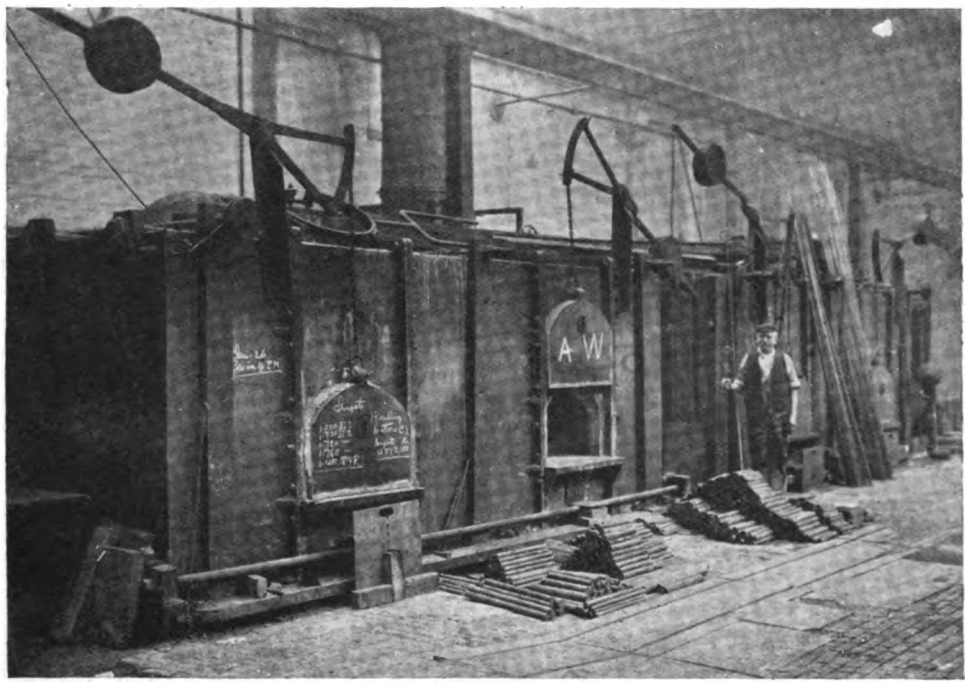

FIG. 7.—EMPTYING AN ANNEALING FURNACE OF "A.W." TWIST DRILL AND CUTTER-BLANKS.

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roughly grind the tools to shape on a dry emery wheel or stone before hardening. By this means the tool, after hardening, requires but lightly grinding, which should be done by hand. When the tools are ground on a wet emery wheel, and undue pressure is applied, the heat generated causes the steel to become very hot, and water playing on air-hardening steel whilst in this heated condition tends to produce cracking.

The "A.W." steel can be supplied in the following and intermediate sizes:—

Round sections,	¼ in. up to 10 in.
Square ,,	¼ in. ,, 10 in.
Rectangular ,,	⅛ in. × ¼ in. up to 1 in. × 12 in.
Bevel ,,	to suit all standard tool holders.

Milling cutter blanks are annealed ready for machining to any required size.

Having described the processes of manufacturing crucible cast steel, from the casting of the ingot up to the hammering and tilting of the steel into bars, it will now be opportune to touch upon the question of high-speed steel, and its rapid progress and development during the last few years; a development that has revolutionised alike the theories and treatment of tool steel, as well as its uses in our engineering shops. In proof of this, we have the paradoxical condition that whereas it was formerly necessary, in treating self-hardening steel, that every care should be taken not to over-heat it (that is, not to exceed a temperature of between 1500° and 1600° F.), otherwise its nature and cutting power would be seriously impaired; now it is one of the essential conditions to heat up the high-speed steel very considerably above these temperatures; in fact, to so high a temperature as 2200° or 2300° F., a temperature which would practically melt pig iron.

This is a truly remarkable paradox, and forms one of the most striking phenomena in the recent history of steel treatment.

Partly as a result of this, it is now possible with the "A.W." high-speed steel to turn and machine steel at a rate up to 400 ft. per minute, and also to drill cast iron at 25 in. per minute! These are indeed remarkable speeds when it is remembered that, only a comparatively short time back, with the ordinary crucible steels, a cutting speed of 30 to 50 ft. per minute was more like the limit.

The above figures must appeal to all as very remarkable. Could our engineering forefathers but return, and be told that such speeds were being attained in our workshops, they would doubtless say: "Politeness forbids a true expression as to what I think of your statement."

It is to Messrs. Taylor & White, of America, that the credit of initiating high-speed cutting is due. It will not, however, be denied that the improvement and development that has taken place during the past few years is due to our own country; for whereas in the Taylor-White process their steel could not be sent out in bars, but only in the form of finished tools specially treated on the nose only: now high-speed steel, manufactured in this country, is delivered to users in the ordinary way; and further, its forging and treatment is absolutely simple: in fact, simpler, and accompanied by less risk, than in the case of ordinary tool steel.

In the case of hardening the point of the tool on the American plan, the author can recall a somewhat amusing story. One such tool was taken and offered for sale to a certain works in the North of England, and the seller was enlarging on its wonderful properties, and stating how cheap it was at 3*s.* per lb. The intending purchaser asked, "But how shall we re-forge and re-harden the point of the tool?" "Oh," was the reply, "you will have to send it back to our works when the point is worn off, and we will re-treat the tool and return it to you with another point." "Oh, indeed," said the buyer. "Now look here; I do not object to giving you your price for that little bit of the nose end, but as to the rest of the stuff behind it, well, say, 1½*d.* per lb. for that!"

It will, therefore, be seen that the very exceptional treatment required in preparing these tools precluded their adoption and use commercially; and it is a remarkable fact that the English manufacturer is now exporting high-speed steel on a large scale to America.

In forging, annealing, and hardening crucible steels, it is essential that the most suitable temperatures should be found for all of these processes, and that accurate means be taken to ensure such temperatures being actually obtained as near as practically possible. This can only be effected by the skilful use of pyrometers, for to work on the old-fashioned lines of judging by the eye is no criterion of actual temperature. It is now known that every composition of steel has its own definite temperature, best suited for obtaining the most satisfactory results; and the nearer this can be worked to the better, any deviation from the correct temperature, up or down, involving a corresponding difference in the efficiency of the steel.

On the question of heat-treatment of steel,

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it is indeed remarkable what divergent effects different temperatures of heating produce on its molecular structure. Looking at a bar of steel, one can scarcely believe that it contains so much mystery and complexity. For example, a bar, if it be heated to a certain temperature, may be left in such a molecular condition as to be practically useless. Heated up a little higher, its structure is completely altered, the bar attains a good condition, and is rendered tenacious and ductile. Again, if

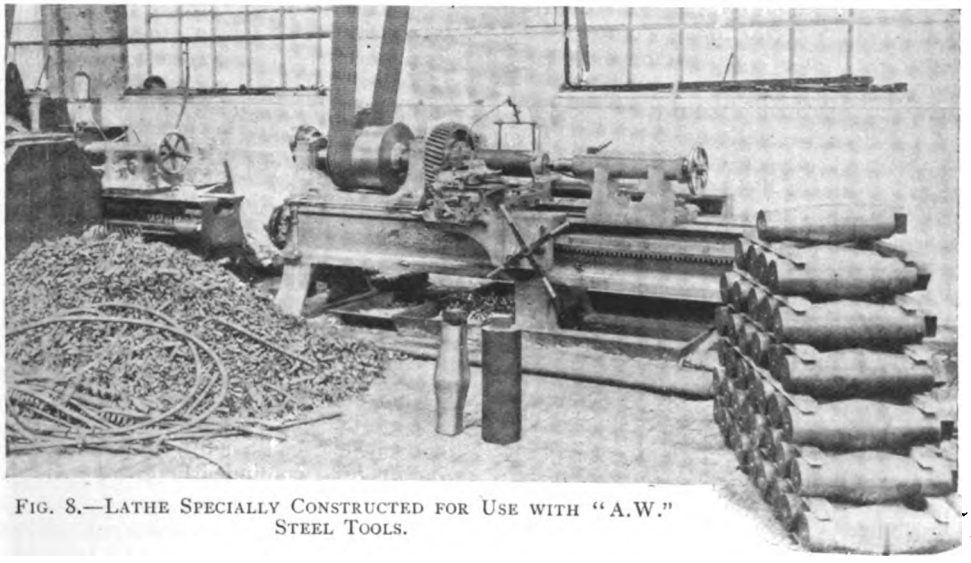

FIG. 8.—LATHE SPECIALLY CONSTRUCTED FOR USE WITH "A.W." STEEL TOOLS.

we take another bar of steel of certain composition, we may heat it to a certain temperature, when its molecular structure will be such that it can be cut and shaped into any desired form; but go a step further, and heat this bar to a still higher temperature, and rapidly cool it, its molecular condition has again changed. The bar has become intensely hard, and is capable of cutting softer steels—it has, in fact, become tool-steel. If the steel is heated to a still higher temperature, it is in ordinary phraseology termed "burnt"; if you then rapidly cool it, the steel is still hard, but its structure becomes granular, and therefore very brittle. Its tough nature and cutting powers have become impaired; in fact, its molecular structure is again changed.

Having dwelt on the manufacture of crucible steel, it will now be interesting to refer to the use of it; and more particularly to the use of high-speed steel and of some actual practical work done with it. It has been stated by some that there is not much advantage in its use; but it is easy to disprove this statement. It has been proved beyond doubt that it is distinctly economical to use high cutting speeds, this being clearly shown in the conclusions arrived at by the Manchester Association of Engineers as a result of an exhaustive series of tests and trials with high-speed tool steel. These trials extended over a period of many months, and were carefully carried out under the superintendence of Dr. Nicolson, Professor of Engineering at the Manchester School of Technology, together with a specially appointed Committee, and the tests were of a very complete and detailed character.*

Briefly, some of the results arrived at by this Committee were, that although more power is naturally required to take off metal at a high than at a low speed, the increase in power is so small as to be quite out of proportion to the large extra amount of work done by the high-speed cutting. This, one would say, is an important point for all users of steel to bear in mind. Of course, it cannot now be denied that machines which were fully equal to the cutting power of the old kinds of tool steels are now quite unequal to the capabilities of the high-speed steel—not in driving power alone, but in the absence of rigidity and general strength of working parts for obtaining the utmost work that the high-speed steel is capable of performing. Purchasers of machine tools will

* "Rapid-Cutting Steel," by J. T. Nicolson, D.Sc., M.I.C.E.; TECHNICS, No. 1, Vol. I., January, 1904, pp. 84–92.

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doubtless, in obtaining new designs, note this, so that machines, and tool steels to be used in them, shall be mutually adapted.

A proof of this might here be given:—We had at our works an ordinary 12in. lathe, turning armour plate bolts of from 4in. to 5in. diameter, and we thought we did wonderfully well in turning them at a cutting speed of 8oft. per minute. We found the tool at the end of the day's work to be practically as good as at the commencement, and this caused an increase of speed to be suggested.

It was found, however, that the lathe had not sufficient power to admit of any increase of speed, and yet it was felt beyond doubt that if we could only get the required power we could run at double the cutting speed.

We therefore designed a special lathe (Fig. 8) with a width of belt increased from 4in. to 7½in., and an increase of the belt velocity of 400ft. per minute. The lathe was duly put to work, and we immediately began to cut at a speed of 152ft. per minute, the same depth of cut and feed being maintained as when we were cutting at 8oft. per minute; whilst the tool, which is 1¼in. square in section, lasts from 7 to 8 hours without requiring to be re-ground. Fig. 8 shows the lathe in which these splendid results were obtained, as it appeared at the end of one day's work. The plain rolled bar is shown in front, together with the bolts made from such pieces in a period of 10 hours by a 1¼in. square tool.

The bolts machined in this time were 40 in number, as against a production of only 8 when using ordinary self-hardening steel. The following are the actual cutting speeds and feeds on these bolts:—

Cutting speed, 152ft. per minute; depth of cut, ¾in.; feed, 32 cuts per minute. Actual metal removed, 62lbs. per bolt, or 2,480lbs. in the day of 10 hours.

There is another point raised by some users of high-speed steel, and that is as to its having been found brittle. This, however, is not the case if the steel is properly hardened, the hardening being confined to the cutting area, and proper support being given to the tools when fixed in the machine.

One example may be given to show the great pressure-resisting powers of high-speed steel. An "A.W." tool 1¼in. square section, cutting a steel forging at 25ft. per minute, 7/16in. depth of cut, with a feed of ⅜in. per revolution, and removing 14¼lbs. of metal per minute, 855lbs. per hour, withstood easily the very great pressure, which such heavy cutting as this put upon it, without showing any signs of weakness. In practice a tool of about 2in. square section would be used for heavy cutting of this nature. It may be added that a much higher speed than 25ft. per minute could have been attained if the lathe had possessed sufficient driving power.

A subject that must be of the greatest importance to all engineers is that of milling, as by the use of this method of working, a much greater output of production can often be obtained. By the use of cutters made of high-speed steel, still greater economies are effected. Not only can higher cutting speeds be used than when using ordinary carbon steel cutters, but the cutters made from the former can be run for much longer periods without being ground; and as the grinding of milling and similar cutters is a comparatively costly operation, a further economy is thus effected.

In support of these statements, a few results may be submitted, taken from the daily practice at our works. A pair of straddle mills 7 in. diameter, and 1½ in. wide, made of "A.W." steel, were used to cut a ⊥ (an inverted Tee) section from bars of forged steel 7 ft. 3 in. in length, each cutter taking a cut 1½ in. deep, and 9/16 in. wide, at a feed of 1⅛ in. per minute, the cutting feed being 75·5 ft. per minute. After milling 18 of these bars—a total length of 130·5 lineal feet—and cutting continuously for 23 hours, and removing 380 lbs. each, the cutters were quite uninjured; also, the screw-threads on the armour-plate bolts previously referred to are milled at a cutting speed of 330 ft. per minute, with a feed of 15 in. per minute.

It will no doubt be interesting at this stage to give the most suitable processes for the heating, hardening, and tempering of these cutters. It is advisable to first fill up the hole and machined parts, which it is required to keep to size for fitting on the arbor and keys, with common fireclay. Then place the cutters into a cold muffle furnace. Heat up the furnace gradually to a red heat. Then transfer the cutters to another furnace already heated to a very bright yellow (about 2,200° F.) and allow the cutter to remain in until the teeth or cutting edges are heated to the same temperature as the furnace. Place the cutters under the air blast until the temperature is lowered just below visible red, that is, 1,000° F. Remove the cutter from the blast and place in a pan containing tallow, and then heat up the pan to a temperature ranging from 500° to 600° F. Take out, and allow to cool gradually, keeping away from cold draughts.

Some results obtained with the brand of

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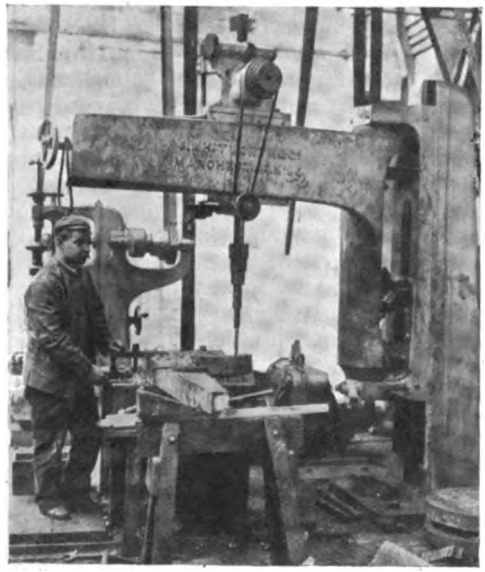
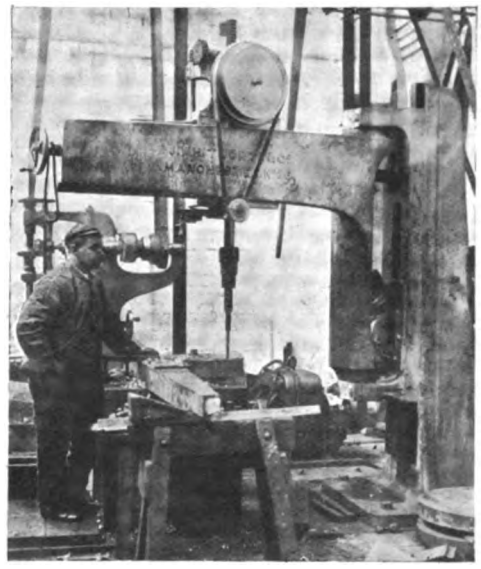
steel which is known as "T.Y.R.," which is an off-spring of the "A.W.," and is specially made for machining hard materials, *viz.*, nickel chrome, and high carbon steels, close grained cast-iron, and malleable castings, may be cited. This brand of steel working on chrome steel projectiles 12 in. diameter machined 20 and was cutting 14½ hours before it required re-grinding. Cutting speed 17 ft. per minute. Depth of cut ¼ in. Feed 12 cuts per inch.

high-speed drill and an ordinary twist drill. Drilling on gun cradles of 5 in. thickness, an ordinary American twist drill completed eight holes only, and then failed, the end being completely burnt up; whilst an "A.W." drill completed 124 holes at the same speed and feed, without suffering any injury whatever. The drills were 2 in. diameter, running at eighty revolutions per minute, and each hole was drilled in six minutes.

The high-speed drills are equally efficient



Machine Geared for Ordinary Steel Drill.



Machine Geared for "A.W." Steel Drill.

FIG. 9.—DRILLING MACHINES GEARED FOR ORDINARY AND HIGH-SPEED STEEL DRILLS.

A development of high-speed work, which was not at first looked for, has been in the manufacture and use of twist drills. Many attempts have been made to produce twist drills from ordinary self-hardening steel, with usually very indifferent success. Now, however, twist drills made of high-speed steel are a practical success, and are largely in use. To those who are not acquainted with the working of these drills, the results obtained from them will be interesting.

An "A.W." twist drill of 1 in. diameter, working on steel plates of 2 in. thickness at 250 revolutions per minute, and 5 in. feed per minute, generally drills 150 holes without re-grinding.

The following is a comparison between a

when used on cast-iron, performing two to three times the work accomplished by ordinary twist drills, as for instance:—At the works of Messrs. Alfred Herbert, Ltd., Coventry, an "A.W." twist drill, of 1 in. diameter, drilled thirty holes through a 3-in. cast-iron block, each hole being drilled at the rate of 7¼ in. feed per minute, the drill being uninjured.

The author has endeavoured to give a brief outline of the "Manufacture and Use of High-Speed Steel." It has not been possible, within the scope of this paper, to go deeply into details of the various stages of manufacture, since many of them would in themselves form the basis of a treatise; he trusts, however, that what has been given will be of some service to those interested in the subject.

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LIMITATIONS TO THE USE OF STORAGE BATTERIES.

By H. M. HOBART, M.I.E.E.

ENORMOUS sums have been thrown away upon misdirected storage battery ventures. To a great extent this has been due to over-estimating the durability of the batteries under the conditions to which they were to be subjected. An annual depreciation of 6 per cent. or less may be attainable with stationary storage batteries, if the current density is low, and expert attendance is provided; but in this case a large initial expenditure is entailed. On the other hand, if the batteries are to be used for moderate speed railway traction, a depreciation of over 300 per cent. per year will inevitably result. Figures ranging from one to the other of these limits will be obtained in the various kinds of work for which storage batteries are used; and it is necessary, in order to determine whether a storage battery can be economically employed in any particular case, to estimate the rate of deterioration corresponding to the conditions of use.

The rate of deterioration, and the specific cost of storage batteries, are both considerably higher than is generally realised. An analysis of the practicability of their employment in any given case should proceed from the basis of considering them in the light of a high-priced fuel of high calorific value, rather than as a type of apparatus. The rate of deterioration, as already suggested, cannot be expressed as a time function; it depends upon the many conditions attending the use of the battery in any particular case. An important factor is the number of complete cycles of charge and discharge. Only the very best of the lead batteries will have a life of some 500 complete cycles of charge and discharge; in other words, it will take a very good battery to show a deterioration of less than two-tenths of 1 per cent. per cycle. Now, when a stationary battery is only discharged once a week, this would correspond to only 10 per cent. depreciation per year; but when, as in automobile cab work, a battery is discharged twice a day or oftener, the battery depreciation will be from 10 to 20 per cent. per month.

By approaching matters from this standpoint, it is by no means impossible to determine whether it is, or is not, economically practicable to employ a storage battery in a given case. Nevertheless, it is much more general to argue that storage battery companies have repeatedly undertaken to maintain batteries for 6 per cent. per annum, and then, if this rate and the initial outlay do not appear prohibitive, to proceed with the undertaking without further investigation.

By the expensive process of repeated trials, it has now come to be generally recognised that storage batteries can have but a very limited use for tramway and railway work. Such use was often attempted in America some 15 to 10 years ago, and experiments were even made with storage battery traction on the Manhattan Elevated Railway. As early as 10 years ago, however, it was, in America, generally conceded that further attempts to employ storage batteries for railway traction work would be futile. Then came a period of activity in Germany, the chief interest centering in the so-called "mixed system," in which trolley cars carried storage batteries to be employed over sections of the line where the trolley wire was considered to be impracticable, on the score of safety, or for æsthetic reasons. The system was for a year or two extensively employed in several large cities in Germany, but was finally abandoned several years ago; for not only was the battery depreciation far in excess of the estimates, but its use on the cars was considered unsanitary.

The most recent, as well as the most elaborate, storage battery installations for traction work were those on certain sections of the Italian railways; at the close of last year these were definitely abandoned. It would be reasonable to suppose that, after such a succession of costly failures, further enterprise on similar lines would be preceded by careful analysis of the data available. Unfortunately, this is hardly likely to be the case. The advent of each new storage battery is heralded by the most exaggerated estimates of its possibilities, and it is generally exploited with but little regard to prior failures and experience.

While there is certainly a legitimate, though limited, field for stationary storage batteries, and probably also for certain classes of automobile work, there is but little reason to expect (pending improvements of the nature of 100 per cent. or more), that storage batteries will be successfully employed for tramway and railway traction.

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In the following example the figures will purposely be taken more favourable to the storage battery than is justified by present experience.

A single track road, with turnouts, connects two towns 50 kilometers apart. A one-half hour service at an average speed of 50 kilometers per hour is required. The average distance between stops equals 5 kilometers. The traffic will amount to 600 passengers each way per day. Four cars, weighing (complete with battery, motors and passengers) 40 tons each, will be on the line at any one time; but it will be necessary to provide eight cars, four of which will be either charging, undergoing repairs, or held in reserve. A car will be recharged after each round trip, *i.e.*, the capacity of its storage battery must suffice to carry 40 tons over 100 kilometers at an average speed (including stops) of 50 kilometers per hour. Such a service, assuming a good road, will require at the motors an input of 65 watt-hours per ton-kilometer; or 2·6 kilowatt-hours per car kilometer; or 130 kilowatt-hours per car per hour. The average output from the battery must thus be equal to 130 kilowatts. Let the voltage be 250 volts; current, 520 amperes. The battery must be able to give an average of 520 amperes during the round trip of 100 kilometers, *i.e.*, during two hours; it must, therefore, have a capacity of 1,040 ampere-hours. It will be assumed that the standard Edison cell will be employed. This cell, at its 75 ampere discharge rate, has a capacity of 150 ampere-hours, thus giving 75 amperes for two hours. Its discharge voltage may be taken at 1·2 volts. Two hundred and eight such cells in series, and 7 in parallel, or 1,456 total cells per car, would be required. Each cell weighs 8 kgs. The battery of 1,456 cells weighs 11·6 tons. Taking the low price of 4·5 shillings per kilogram, the initial cost of the battery would be £2,600. The car would make its round trip of 100 kilometers in two hours; it would then be re-charged, its place being taken by another car. The re-charging would be at the rate of 150 amperes per cell, and it could again be placed in service in one hour. Thus it requires three hours for a car to make its round trip and be re-charged. Each car would make five round trips per day, or travel 500 kilometers per day. The experience with lead batteries, on the Italian railways, showed a life of 12,000 train-kilometers for the positive, and 20,000 train-kilometers for the negative plates. It would appear ill-advised, pending experimental investigations, to assume an ultimate life for the Edison cell of over 60,000 kilometers, *i.e.*, three times the life of the negatives of the lead cell. A life of 60,000 car-kilometers corresponds to 100 per cent. depreciation in 120 days. Hence three battery equipments must be supplied annually. Annual outlay for storage battery per car = 3 × 2,600 = £7,800. This item is to be treated as coal would be for a locomotive. But there is a further expenditure for electrical energy in charging the battery. This may be determined as follows:—

The battery delivers to the motors 2·6 kilowatt-hours per car-kilometer, or 1,300 kilowatt-hours per car day. The energy efficiency, when charging at 1,040 amperes and discharging at 520 amperes, will be just about 50 per cent. Hence each car will require a daily charge of 2,600 kilowatt-hours. At 1d. per kilowatt-hour, this amounts to £10 16s. per car per day, or to £3,950 per car per annum.

Annual outlay for providing storage batteries for six cars *	£46,800
Annual outlay for providing storage batteries for two spare cars †	5,200
Annual outlay for charging six cars	23,700
Total annual outlay for eight cars on account of storage battery	£75,700

A 40-ton car costs, including motors and air brakes, but exclusive of battery, about £1,200; depreciation = 12 per cent.

The road-bed, track construction, and buildings, would come to about £1,500 per kilometer; depreciation = 3 per cent.

Capital expenditure for eight cars	£9,600
Capital expenditure for road-bed, track construction, and buildings	75,000
Total capital expenditure	84,600
Interest at 5 per cent.	4,240
ANNUAL COST.	
Interest on capital expenditure	4,240
All storage battery outlays per annum	75,700
Depreciation on rolling stock, permanent way, and buildings	2,900
Taxes and traffic and administration expenses	5,000
Total annual charges	£87,840

of which 86·6 per cent. falls on the storage battery expenditures.

This line will carry 600 passengers each way per day, which makes a total traffic of 60,000 passenger-kilometers per day, or 21,900,000 passenger-kilometers per year.

To meet the total annual charges, this traffic must yield 87,840 × 240 = 21,000,000d.,

* Three batteries per car per year.

† One battery per car per year.

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which would require a fare of 0·96d. per kilometer, or 1·54d. per mile. To give a fair margin for contingencies and profits, a fare of at least 2d. per mile would be necessary.

The traffic may also be expressed in car-kilometers, and amounts to 3,000 car-kilometers per day; or 20 passengers per car. As such a car would seat some 80 passengers, it is obvious that the load factor of the car (25 per cent.) is as high as could safely be assumed, and that a heavier traffic would require more cars. But as over 90 per cent. of the charges are for the cars and the storage batteries, a more frequent service would bring no remedy.

The low efficiency of 50 per cent. which has been assumed, may occasion surprise. It is taken from the published tests of the Edison battery. A higher efficiency could only be obtained by carrying a greater weight of battery, operated at a low current density. This would obviously lead to still higher costs.

A considerably higher efficiency could be obtained with the lead cell. As we have seen, however, its positives would have but one-fifth, and the negatives but one-third the life assumed for the Edison cell; or, say, an average life one-fourth as great. Hence, on the road in question, a new battery would be required once per month. The lead battery would be somewhat heavier, but on the other hand would cost but one-third as much per kilogram; *i.e.*, some 1·5 shillings per kilogram, as against at least 4·5 shillings per kilogram for the Edison cell. It is evident that these diverse properties of the two types of cell approximately offset one another, and the economic practicability is about the same in the two cases.

It is not so much with a view to the tramway question that this comparison is of value, as it is to emphasise the difficulties attending the use of electricity on automobiles. If electric automobiles are successfully introduced, it will be in the face of difficulties of the same nature as those revealed in the above analysis.

The estimation of the cost for automobile work cannot be made with much precision. The results of one of the most recent estimations (see *The Electrician* for June 3, 1904, p. 268) for heavy slow-speed delivery wagons, which offer the best conditions for the storage battery, were as follows:—

The wagons weigh one ton apiece, cost £500, and cover 30 miles (48 kilometers) per day in commercial service in New York City. After 95 days (4,300 kilometers) the battery requires elaborate cleaning, which necessitates cutting all the connecting straps, washing the mud from the plates and the jars, and reconnecting the cells. After another 75 days (3,400 kilometers), a second overhauling is required, and some replacement of parts. After a further 60 days (2,700 kilometers), the positive plates are replaced, their total life having been 10,400 kilometers; about the same result as was obtained on the Italian railways (12,000 kilometers). It is stated that the negatives have an average life equal to 1⅞rds. that of the positives, here again confirming the experience in Italy.

The total annual outlay per wagon, for upkeep of battery, works out at £81, and a further £24 per annum is expended in charging the battery.

Thus the total outlay for battery is . . .	£105 per wagon per annum
Tyre maintenance . .	£ 36 per annum
Repairs and depreciation of wagon . .	£ 51 „ „
Interest on investment.	£ 25 „ „
Total cost per annum =	£217 *

The wagon covers 13,900 kilometers per year. The cost is thus 3·7d. per wagon kilometer, and also per ton kilometer. In the railway instance which we worked out, the cost comes to 0·48d. per ton kilometer; for although the speed is some four times higher, there is greater economy per ton due to the 40 times heavier car, and due to the better traction conditions on rails. Thus a similar analysis for a 5-ton delivery wagon shows a cost of but 2·7d. per ton kilometer. The New York one-ton delivery wagon requires an input to the battery of 300 watt-hours per ton kilometer. This high value is due to its small weight, the frequent stops, and the high tractive effort required on city streets.

Even for stationary work, the writer is of the opinion that in at least 75 per cent. of the cases where storage batteries are employed, an analysis of the costs would show that greater economy could be obtained in other ways. Stationary storage batteries for central stations and sub-stations generally consist of cells weighing up to 140 kilograms each. These, when of the lead type, cost something like 6d. per kilogram—about one-third the cost of the smaller cells employed in automobile work. Nevertheless, a careful analysis rarely shows any economy to be attainable over alternative methods, by the use of storage batteries.

* This estimate does not include administration expenses, taxes, etc.

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ELECTRIC TRACTION.

The Lorain Surface Contact System at Wolverhampton.

By R. BORLASE MATTHEWS, Wth. Exb.

QUEEN'S SQUARE, WOLVERHAMPTON.

THE April number of TECHNICS contained a general review of surface contact systems of electric traction. Very few of these have passed through the experimental stage into commercial use; of those that have, it is proposed to refer to one in particular, namely, the Lorain system, as laid down at Wolverhampton. There is no test like that of time and constant usage, to demonstrate the value of any such system. The Lorain system has survived the ordeal triumphantly; so that, not only has the existing system, which was on trial, been taken over by the Wolverhampton Corporation, but it has also been decided to double the length of the existing track, making it up to a total length of twenty-three miles. The contracts for the extensions have been let, and the work is being rapidly pushed on.

The first mile of this system laid in Wolverhampton was brought into regular operation at the beginning of 1902; and the first 11½ miles were practically completed at the opening of the Arts and Industrial Exhibition, held in Wolverhampton during the same year.

A general description of the apparatus used will first be given, with the principles of its operation; to be followed by a few notes on the practical working of the system, with special reference to the experience gained during the time it has been in use.

The Lorain Surface Contact System belongs to the class in which electro-magnets, carried underneath the car, operate switches in the contact boxes on the track when the car passes over the latter. Thus, many of the objectionable features, which are inherent in all systems having electro-magnetic mechanism located below the surface

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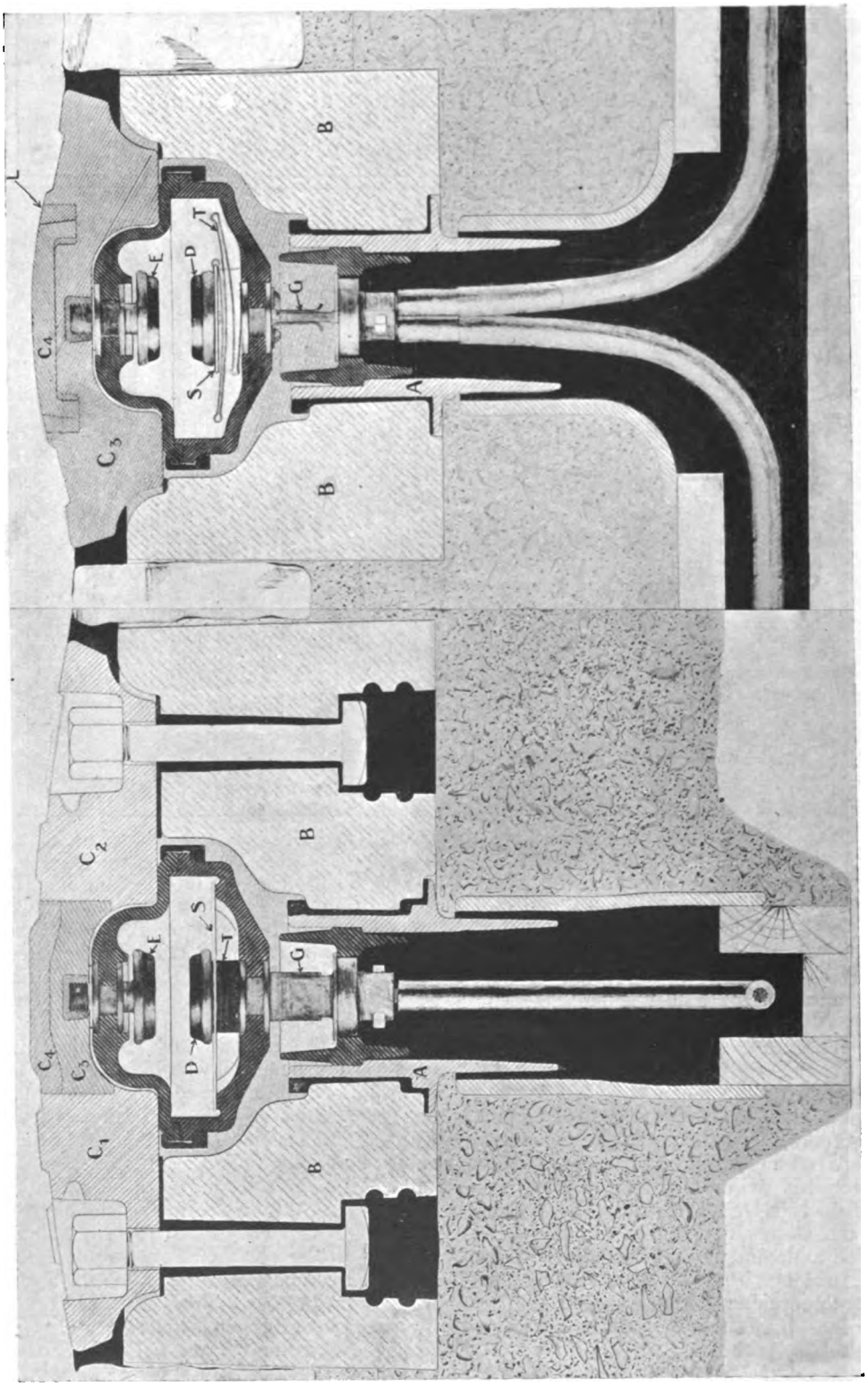

Transverse Section. *Longitudinal Section.*

FIG. 1.—SECTIONS OF CONTACT BLOCK, LORAIN SYSTEM.

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of the road, are avoided. One special advantage is, that a defect in a magnetic coil cannot by any possibility leave a "live" contact plate when the car has passed.

The moving part of the switch located in each contact-box is extremely simple. It consists of a flat piece of iron, with a carbon disc attached to its upper surface, while a flexible copper strip joined to the under side of the disc connects the latter to the live feeder.

The switch is enclosed in a hermetically sealed case made of a non-conducting material, "vulcabeston." Fig. 1 gives cross and longitudinal sections of this case, which, it can be seen, is made in two cup-like parts held firmly together (so as to be water- and air-tight), by means of a gasket and annular screwed ring. In the top and bottom of the case are two brass terminals moulded into the insulating material. The top terminal screws into the under side of the metal cover of the contact block, and supports the cup. The bottom terminal serves to connect the inside of the cup to the cable terminal, by means of spring contacts G, which clamp a tongue on the latter, as indicated in Fig. 1. Inside the case a carbon contact E, about 2 inches in diameter, is attached firmly to the upper brass terminal; and a second similar carbon contact, D, is secured to a soft iron plate S, $4\frac{3}{4}$ inches long, 2 inches wide, and about $\frac{1}{16}$ inch thick, which is the armature to be acted upon by the magnet carried by the car. This armature usually rests upon a ledge in the interior of the cup, as shown in Fig. 1; it is connected to the lower brass terminal of the cup by means of a thin hard rolled copper strip T, folded upon itself, as shown in the longitudinal section. This connecting strip not only makes electrical connection to the armature, but also serves as a guide to the latter in its vertical movement, without adding any friction or liability to remain up after the magnet on the car, which caused it to rise, has passed away.

The cover is not of quite such simple construction as appears on first sight. As can be seen from the cross section of the contact block in Fig. 1, it consists of four parts, C_1, C_2, C_3, and C_4. The two outer parts C_1 and C_2 are of cast iron, while the central part C_3 is formed of extremely hard non-magnetic steel. Covering the top portion is a small renewable piece of the same material, C_4, arranged to take the wear of the collecting shoe, and secured by running in molten lead; the lead joint is clearly shown in the longitudinal section (Fig. 1) at L. The covers are grooved to prevent horses slipping on them.

The block B is made from material known as "reconstructed granite," which has very high insulating properties. A slight recess is formed to take the cover, and an opening is made for the cup containing the switch. Below this is a hole containing a cylindrical casting A, the bottom of which enters a Y-casting, thus protecting the cable as it rises from the trough in which it is laid in the centre of the track. The top end of this cylindrical casting supports the cable terminal insulator. The insulated feed wire, which is of a much smaller section than the ordinary overhead trolley wire, is looped into the contact box and then mechanically clamped and soldered to the cable terminal, so that a good electrical connection is made. This cable clamp would be liable to surface leakage if any moisture got into the block. To avoid this, the interior is filled with a special non-oxidising, insulating oil, which does not thicken in cold weather or deteriorate in any way. As the oil is heavier than water, any moisture that may enter will rise to the top, away from the live terminal altogether.

The cover, or contact plate, as at present used, measures 15 in. long by $9\frac{1}{2}$ inches wide; the old size was $12\frac{3}{4}$ inches long by $6\frac{1}{4}$ inches wide. Thus a better protection is now given to the top of the block: the cover does not end so abruptly at the edges, and consequently offers less obstruction in the road. It is held in place by two bolts inserted in the block. On removal of the nuts, the cover and box of insulating material containing the armature may be lifted out for inspection or replacement.

The electro-magnets used for closing the switches are suspended underneath the car, and are six in number. Owing to the space they require, the trucks are fitted with wheels of a diameter larger than usual, namely, 30 inches; thus the motors are raised to a greater distance above the track than is customary, leaving ample room underneath for the projecting pole pieces of the magnets and the collecting shoe.

The magnets are of the horse-shoe form, as shown in Fig. 2. To make the magnet system as rigid as possible, the pole pieces are firmly bolted together by aid of pieces of wood, thus forming a solid structure without interfering with the magnetic circuits. The pole faces are kept clear of the contact blocks, as is shown in Fig. 2, where the path of the magnetic circuit, when one of the magnets is over a contact stud, is indicated.

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The distance between the two limbs of the magnet being greater than that between the pole faces and the stud, the magnetic lines naturally tend to go through the latter, since this is the path of least reluctance. If the top of the contact stud were made entirely of magnetic material, it would serve as an armature and complete the circuit; but as was pointed out above, the centre of the stud is made of a non-magnetic manganese steel, so that the field extends beneath into the switch-box. When this occurs, the soft iron plate in the latter rises so as to assist in completing the magnetic circuit, and in so doing makes contact with the carbon block at the top of the box, as is shown in Fig. 3; making the stud alive, so that current can be taken by the collecting shoe.

There is very little fear of the armature being held up, after the car has passed, by any residual magnetism left in the contact plate; for not only are the outside parts made of a very permeable iron, that quickly loses its magnetism when the magnetising force is withdrawn; but also, since these outside parts are separated by the non-magnetic steel, the iron cannot be magnetised as a whole by induction. Should there be any tendency to this in the cast iron, it would be in the weakest and most unstable direction, namely, its thickness.

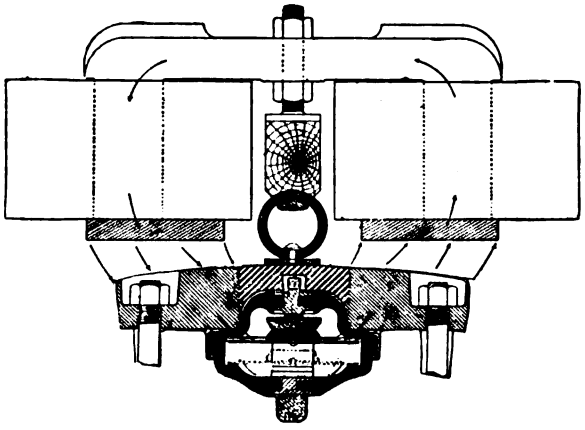

FIG. 2.
TO ILLUSTRATE METHOD OF WORKING, LORAIN SYSTEM.

The electro-magnets are compound wound; one of the windings is connected as a shunt across the live stud and the rail, and the other is put in series with the motors. When the car is at rest, the shunt winding keeps the contact box switches closed, and consequently the studs remain alive; so that the car can be started immediately, without the preliminary operation of closing the stud switches. A shunt winding cannot alone be depended on for the excitation of the magnets; for if the motors are temporarily overloaded, the excessive current will cause the line voltage to fall, thus weakening the excitation due to the shunt winding. The addition of a series winding ensures that the pressure holding the carbon contacts together shall increase with the current passing through them to the motor.

A battery of eight accumulator cells is provided for each car; this can be connected by a switch to the terminals of the series winding of the magnets, and thus the contact switches can be operated on starting the car for the first time, or if for any reason the line current has temporarily failed.

Conveniently situated on the driving platform, near the main controller, is a special three-way switch for operating the magnet-exciting circuits. Normally, it is kept in the mid-position by springs, but at the option of the driver it can be pushed to one side or the other. In the mid-position the shunt and series windings of the magnets are excited. If the switch is pushed to one side, the series winding is connected to the accumulators; and if moved to the other side, the magnets are demagnetised. This latter operation is useful at times when one of the magnets has picked up a piece of iron on the road, and the driver desires to drop it to avoid a short circuit.

Between the magnet poles is placed the collecting shoe (shown in section in the middle of Fig. 2), which is of a very ingenious construction, consisting of a copper strip about twelve feet long attached to a piece of heavy rubber hose, the latter having canvas insertion to give it increased rigidity. The hose in its turn is fixed to a wooden support, which is secured to the magnet frames by adjustable bolts, so that the whole shoe may be raised or lowered as desired. The contact studs are spaced ten feet apart; so that to ensure the current collection being as continuous as if it were taken from a trolley wire, the shoe has to be made of sufficient length to bridge the distance between two adjacent studs. A long shoe, that will be durable, efficient, and noiseless, is very difficult to construct. Not only must it possess these qualities, but it must also be sufficiently flexible to allow for irregularities

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in track construction and paving, and yet be rigid enough to make the current collection positive and continuous; also, it should be easily and cheaply maintained. The contact strip must be made of a non-magnetic material, so that it cannot attract to itself any loose pieces of scrap iron that may be on the track, and so cause a short circuit. All these conditions seem, however, to have been very successfully met by the type of shoe adopted at Wolverhampton. The noise made by the collecting shoe is not noticeable; this in itself is an improvement on certain other surface contact systems, in which a disagreeable clanking sound is heard as the car passes over each contact.

The copper collecting strip is of a commercial size, and only requires the ends bent up and a few holes drilled before it can be attached to the holder. The wear takes place at the bend, where it strikes the stud; when this part has become too thin, the strip is removed and sold by weight as old metal.

The poles of the suspended magnets extend over a space of sixteen feet, so that the armature in the contact box is raised and the stud made alive before the collecting shoe reaches it; it also remains alive until after the shoe has passed over it. Thus no arcing can take place inside the contact boxes, for no current is passing when the switches are opened or closed. Should there be a leakage current, the switch would have to break this; but such a current is likely to be small, and the carbon blocks will prevent the surfaces in contact from fusing together.

In April last the students of the Institution of Electrical Engineers visited Wolverhampton to see the Lorain system in operation. Mr. C. E. C. Shawfield, the borough electrical engineer, showed the party over the system, and very kindly gave them a number of details of his experience of the operation of the contact studs and collecting apparatus, and their behaviour after having been in regular use for some little time. This was especially interesting, as very little has been published regarding this matter. Mr. Shawfield is well satisfied that the system is even more trustworthy than the overhead method.

Very complete tests have been carried out on some of the switch boxes by aid of a special piece of apparatus, consisting of a magnet, similar to those mounted under the cars, fixed to a frame which is supported on bearings and rotated by an electric motor, so that the magnet passes over the contact stud under test and operates the switch inside it once every revolution of the frame. Though prolonged tests have been made in this way, the switches have shown no sign of getting out of order or otherwise failing to operate.

The total weight of the apparatus on the cars required to operate the contact stud switches is about one ton.

The wiring of the cars can easily be arranged so that, if a trolley pole is provided, current can be collected from an overhead wire. Cars fitted with the double collecting apparatus can therefore run on combined systems, thus allowing of through services from outlying trolley sections or neighbouring towns. It was at first proposed to have a dual system at Wolverhampton; but the committee has now decided to adopt the surface contact system throughout. Arrangements are pending for the running of certain of the Wolverhampton District Company's trams which are at present equipped with the overhead trolley, over the Corporation's system, by equipping them with the necessary collecting apparatus.

The average leakage on the line is one-tenth of an ampere per car in service, which is not in any way an excessive figure, comparing as it does very favourably with overhead construction. The only time when leakage causes serious trouble is in the winter when salt is used for melting the snow on the lines: the brine forms a good conducting path between the live stud and the rail as the car passes. The gauge is 3 ft. 6 in., but experience indicates that for a surface contact system, the standard gauge of 4 ft. 8½ in. would have been much more satisfactory, as the surface leakage path would be greater.

Some little trouble has been encountered with the blocks which hold the studs, owing to cracking and breaking with the heavy traffic passing over them, and a slight movement of the bed of the track; but this has been overcome by the use of specially selected material for the construction of these blocks, and larger cover plates are now used, which completely protect them. These larger plates, being purposely curved on top, offer much less resistance to wheeled traffic than the older pattern; for though their height above the track at the centre is the same as in the older pattern, the greater width allows them to taper gradually down to the level of the stone setts at the edges.

One of the inconveniences that has to be contended with, and one that would hardly have been anticipated, is due to picking up, by the suspended magnets, of pieces of scrap iron which have fallen on the track. These pieces of iron, when the car is passing over

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points and crossings, frequently cause a short circuit, opening the circuit breakers on the feeder panel in the power station. When the driver finds that he has in this way picked up a piece of iron, he cuts the magnet windings out of circuit by means of the special switch mounted near his controller, thus causing the adhering piece of iron to drop off. Having done this, he excites the series winding on the magnets by aid of the current from the accumulators carried on the car for the purpose, so that the stud switches can be operated again. Wolverhampton being a manufacturing town, where much stamped iron and steel is used, the track is specially liable to get scrap and waste iron dropped on it from passing cartloads of such material. In one corner of the car barn there is a large heap of iron scrap which, from time to time, has been picked up by the cars in this way.

The time required for replacing defective contacts is very small, the average being about twenty minutes. This operation is, of course, more difficult in winter, when the road is frozen and the congealed mud has to be chipped away. A small handcart is kept at the car-shed, with a supply of spare parts and the necessary tools, which are of a very simple character. The gauge of the wheels of this truck is the same as that of the tramway track, so that by means of a special attachment it can be hooked on to a tramcar and thus quickly towed to the place of breakdown. The number of failures, however, has been very low, 90 per cent. of the contact boxes having been left unopened even for inspection. The remainder have been opened so that the results of regular use on the switches might be observed; only a few instances of failure, where either the switches have failed to operate or remained alive after a car had passed, have occurred. In most of the cases where the switch-boxes have been left alive, though a high-resistance Weston voltmeter placed across the contact stud and the rail indicates 400 or more volts, yet the area of contact is often so small that only a very small current can pass, and a live contact is rarely harmful. One such live contact was tested by the writer. With one foot on a stud and one on the rail, nothing was perceptible; with one hand on the rail and one on a stud a slight shock was felt on making a loose contact with one finger; but on applying an ordinary pressure, nothing was felt at all,

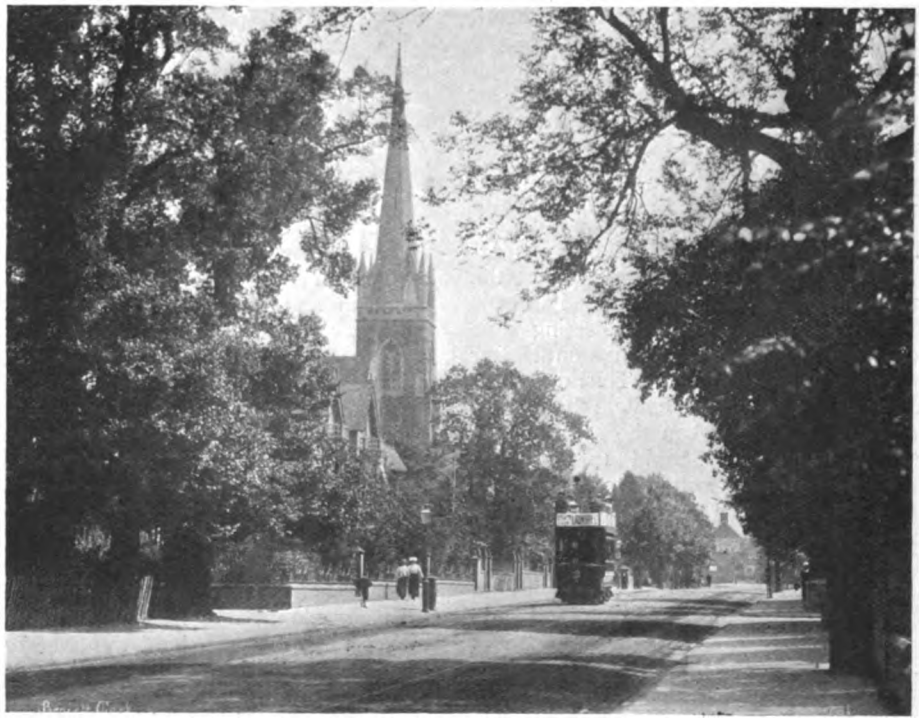

FIG. 3.—TETTENHALL ROAD, WOLVERHAMPTON.

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though the Weston high resistance voltmeter gave a high reading.

Once a week the whole of the contact boxes are tested by placing a voltmeter across stud and rail. The boxes at junctions and crossovers are tested daily. Formerly a man walked round the track with two sticks having contacts connected to the voltmeter. This was rather a long proceeding, taking over two days: so Mr. Shawfield has lately devised a much improved method, by which the whole track, which is eleven and a half miles long, can be inspected in about two and a half hours. A voltmeter is fixed in a car of which the collector magnet windings are cut out, so that it does not operate the switches; one terminal of the voltmeter is connected to the collecting skate, and the other to the car frame. This car is then towed over the route by another car, and a man stationed in the car observes the voltmeter readings.

Mr. Shawfield has instituted careful inquiries throughout the country to find out the average number of car journeys lost through defects and accidents to the distributing system; the result shows that the losses under the Lorain system are very small compared with those met with in the case of overhead construction.

The line is divided into 100-yard sections, with feeder pillars every 200 yards; in the extensions the same length of sections will also be adopted. A section has not, as a rule, to be cut out to replace a defective switch, so that interference to traffic is reduced to a minimum.

The general result of the experience gained is that the surface contact system at Wolverhampton has proved as satisfactory as an overhead system would have been, with the advantages that it is not so unsightly, and danger from falling overhead wires is entirely obviated; several such accidents having occurred in neighbouring towns was a strong point in causing the Town Council to adopt this system. It must be admitted, however, that accidents of this nature are not very frequent.

The chief question that has to be considered, therefore, in adopting this system for a new track, is that of initial capital cost, which is in the ratio of about 6 : 5 if single track, or 12 : 5 if double track is used, as compared with the overhead system. When comparison is made between it and the conduit system, a ratio is obtained greatly in favour of the surface contact system. Arguments advanced for the adoption of the conduit system also hold good for the surface contact, the latter having the great advantage of smaller capital cost and being free from drainage difficulties. The studs, especially those of the new form, offer much less obstruction to traffic than the six-inch-wide slotted rail of the conduit system. The overhead trolley system will still hold its own, however, on account of the difference in capital cost; especially where double tracks are adopted, as they must be in electric traction to ensure a rapid and convenient service. There is a practical objection to the adoption of single track in that the rails wear unevenly, the parts between the crossings being used oftener than at the crossings; the wear and tear of points has also to be taken into account. If the surface contact system be adopted with a single track, there are additional disadvantages which counterbalance the lower capital cost as compared with that of the double track; such as the increased tendency to surface leakage at points and crossings, owing to the shorter distance between the blocks and the rails; and the shorter life of the copper strips in the switch boxes, owing to the more frequent bending.

As can be seen from the photographs accompanying this article, the Lorain system does not disfigure a pretty road or a business thoroughfare: this is especially noticeable at junctions and open spaces.

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THE FORMATION OF LOOPS
AND
THE CONSTRUCTION OF LOOPED FABRICS.

PART II.

By JAMES HY. QUILTER, F.K.C.

WARP LOOPING.

IN the foregoing examples the threads have been laid across the fabric from one side to the other, on the principle of plain knitting. There is, however, a principle of knitting distinctly different, in which the fabric is composed of a number of threads which are knitted in a vertical direction, and are looped together sideways. Each thread so forms a chain of loops from end to end of the fabric, and not from side to side. This principle of knitting is known as *warp knitting*, by reason of the threads taking a position similar to the warp threads in a woven fabric.

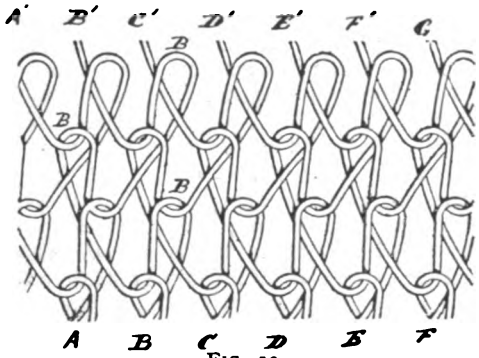

FIG. 13.

Fig. 13 is an example of a simple warp-looped fabric with separate threads, A B C D E and F to each needle. These first loop on a needle to the right at one row, and next on a needle to the left, as shown at B, B, B, B, each terminating at A^1, B^1, C^1, D^1, E^1. Thus, at each row thread A is looped on thread B, thread B on thread C, etc.; and at the next row thread B is looped on thread A, and thread C on thread B, etc. In warp knitting, there being one thread or more to each needle, a much greater variety of threads may be used, and as the threads may be sub-divided into sets, each set may have a movement independent and distinct from any other. This establishes a principle in which scope for colour and design is unlimited. This being so, it is in this branch of the knitting industry that the designer finds an opportunity to display his art; for to design a fabric on a machine with some four or five thousand needles, and with as many as eight sets of warps, the movement of each set of warps to produce combination of colours, with arrangement of loops, must of necessity require not only a knowledge of the machine, but also a thorough adaptability as to the principle of looping.

The general principle upon which threads are laid in warp looping may be divided into —first, the principle of laying the threads so that at each row a loop shall have a side connection with one or other of the side loops, this being the principle shown at Fig. 13: second, the formation of open designs by the threads being laid so that only for a given number of rows shall such sideway connection exist, and this only at direct intervals; and the periodical changing of the threads' connection with each other so as to form a varied design: third, by the traverse of the threads, so that, by the crossing and re-crossing of each other, colours may be combined so as to produce varied desired effects; and fourth, by the laying of one set of threads to form endless chains of loops on one needle only, and connecting such chains by other threads having a sideway traverse.

Fig. 14 shows the looping of a fabric following the second principle named, the two threads, A^1 and A^2, each having a separate motion, and moving as shown, making a connection by the movement at rows 2, 3, 4, and 6, 7, 8, while the adjoining thread would make a similar joining on both sides at

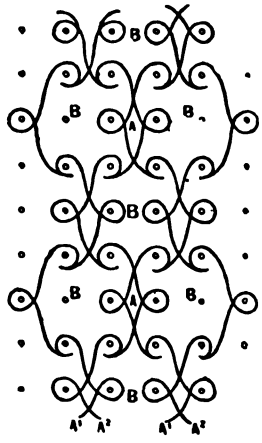

FIG. 14.

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rows 4, 5, 6. Thus, small pillars A, A, are formed with openings B, forming a lace-like net fabric.

Fig. 15 shows the traversing of the threads following principle three. Here thread A forms its loops from left to right, and thread B from right to left, and with such changes that at 1 each needle has both loops.

The forming of loop chains on the one

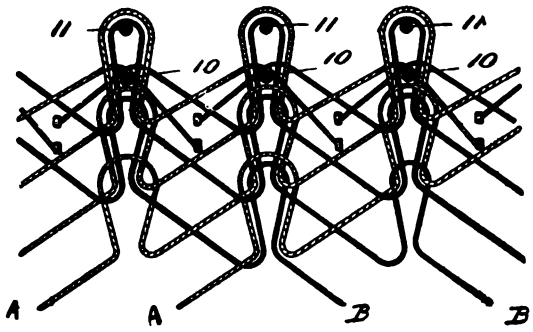

Fig. 15.

needle, as adopted in principle four, follows the crochet form of looping, as will be seen from Fig. 16, which shows two such chains, A being shown in black, and B in white effects. These chains have no connection with each other, being connected by the threads of other bars, so laid as to be looped in with the chain combining them into fabric of different designs, as shown at C and D, where in each the movement of the connecting thread is looped in a different manner.

Fig. 17 shows the method of chains looped together to form an open-work design. The chains are formed on needles 1, 2, 3—6, 7—10, 11, 12. Threads A and B, by looping with chains 1, 2, 3, connect them at intervals, as does thread C at chains 6 and 7, and threads D and E with chains 10, 11, 12. These are

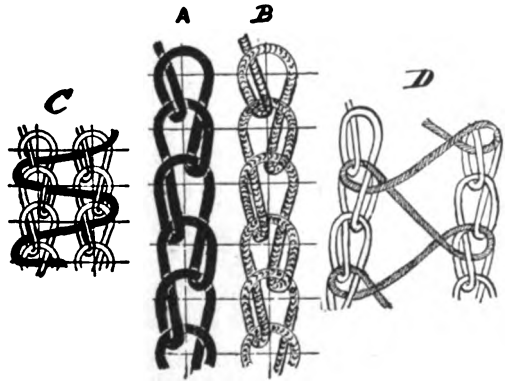

Fig. 16.

again joined by threads F and G, which have a traverse over the two needle spaces 4, 5 and 8, 9, thus producing the open effect; these looping threads being looped in on either of the principles shown at C or D, Fig. 16.

The transferring by sideway movements of the threads will also connect the chains, as will a wrapping of the threads of one chain round the needle of the adjoining chain, and back again, continuing its looping on the original needle.

The formation of loops made on these principles, both separately and in combination with each other, forms the most interesting study in the whole of loop formation.

The two principles of loop formation (distinct as they are, forming the basis of two kinds of looped fabrics) have become so closely allied that the adoption of the two in one fabric is becoming more and more developed; for by such methods fabrics of different characters can be produced. It is by the combining of the two principles that not a few of the present day fancy looped

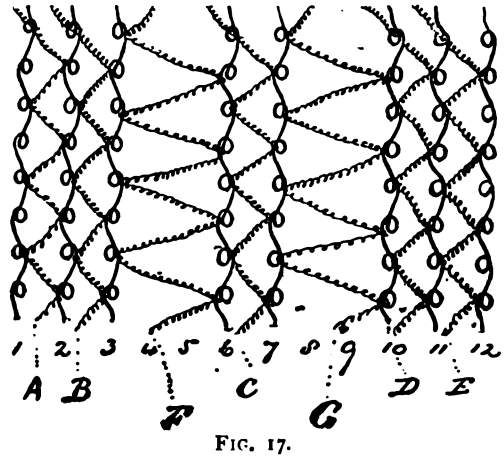

Fig. 17.

fabrics are produced, as by the principle of plain looping a plain fabric can be made; and upon this, during the process of manufacture, may be worked certain designs by warp threads looped on the principle explained. To such an extent has this been done that the warp loops may appear on the front of the fabric, making a fixed design; or the two threads may be looped together, forming a mingling of colours, thus producing quite different effects. Vertical lines at equal distances apart may be laid on plain fabrics by adopting the chain method of loop forming as explained at A B, Fig. 16, while by the sideway movement of such looping, zig-zags

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and other symmetrical designs may be made from the single lines to the more elaborate designs.

Fig. 18 shows a few methods of looping the warp threads on a plain looped ground: A shows looping on a single needle only; B on two needles; C on four needles. D shows the looping for a three-needle wide zig-zag, and E a similar design with different movements, while F is a more solid design.

Fig. 19 shows a design with the two threads intermingled. A B C D represent four different colours forming the ground, each colour being worked for six rows from side to side of the fabric. A^1 B^1 C^1 D^1 show the same colours as warp or vertical threads, each laid on six needles; thus each colour

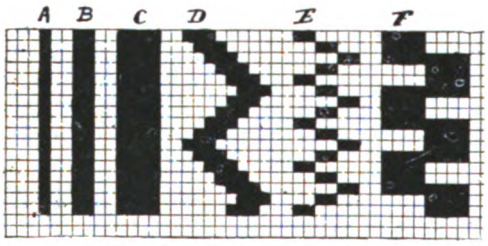

Fig. 18.

intermingles in the form of squares, producing plaid-like effects, the threads running from end to end of the fabric.

Fig. 20 shows a part of one of the more elaborate designs that can be made on this principle, the ground-work being in a self colour with the design in silk, 47 warp threads loop at 47 needles, each thread

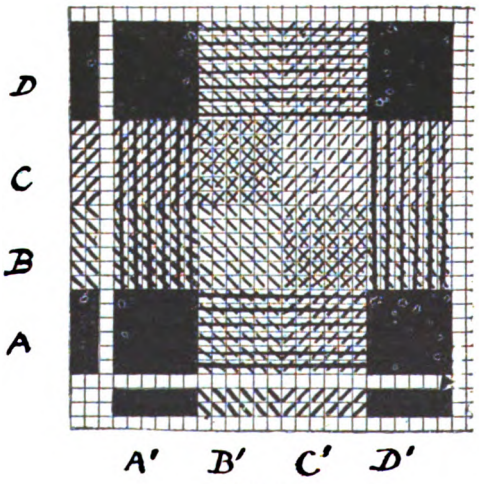

Fig. 19.

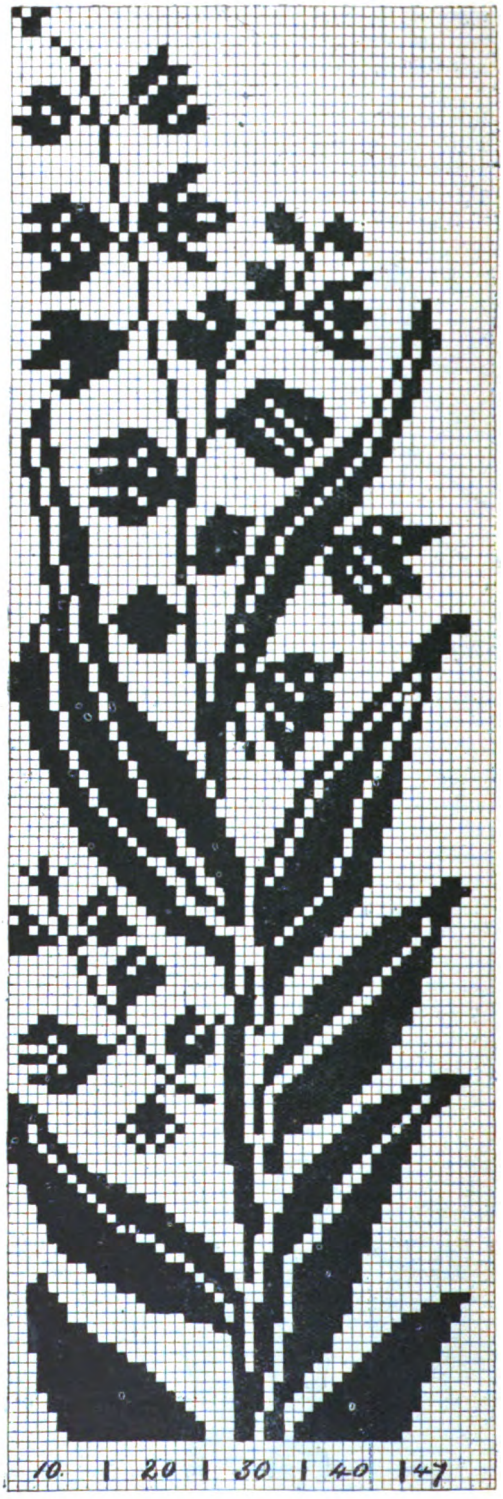

Fig. 20.

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looping only at such rows as may be required in order to work out the design on the principle shown; when not so looping, the threads appear at the back as vertical threads.

Perhaps it would be more definite to apply the term warp and weft knitting to those looped fabrics which are formed partly by looping and partly by the introduction of straight threads; for such fabrics are made, in which straight threads are laid in at each row of looped threads, somewhat on the principle shown in Fig. 21.

Here the straight threads g^1, g^1, g^1, are held in by the looping of the ordinary thread. It is on this principle that elastic knitted fabrics are produced and so largely used for medicinal purposes, the threads g^1, g^1, g^1 being, in such cases, rubber threads.

Threads running vertical may also be

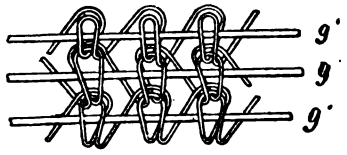

FIG. 21.

looped in a similar manner, or as shown at Fig. 22.

In this case both the warp and weft threads are looped in as shown, *a*, *a*, *a* showing straight threads running from end to end of the fabric, or warp threads *b* and *d*, straight threads running from side to side alternately on the principle of weft threads, but differing in so far that they are in no way connected to the warp by intersecting, the connections being made by the thread *c*, which is looped on the first principle of looping.

Loop formation thus produces perhaps a greater diversity of fabrics than any other principle of producing textiles; for besides being distinctly differentiated from all others by the fact of it being a looped fabric, it

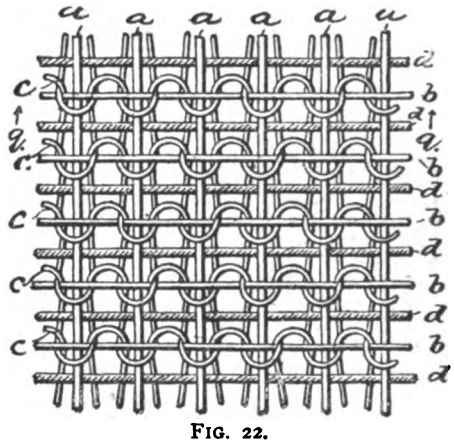

FIG. 22.

forms a connecting link on the one hand with twisted fabrics, by reason of the open lace-like effects that can be produced by one or other of the loop formations explained; and on the other hand, with woven fabrics. By the introduction of straight warp and weft-like threads, firm fabrics, void of elasticity, are made with the same characteristic and finish as ordinary woven cloths; while looping, with its special elasticity and looping formation, forms a study second to no other principles of thread manipulation.

THE "NASCENT STATE" IN THERAPEUTICS.

A RECENT communication by Dr. Albert Robin to the French Academy of Medicine is both interesting and important. It deals with the influence of the nascent state on the action of drugs, shows how this action may be increased, and a maximum effect produced by a minimum dose. The remarkable properties of oxygenated water are explained as due to the fact that in contact with organic tissue, nascent oxygen, *i.e.*, oxygen in its "highest energy condition," is liberated. Antiseptic properties may be added to the ordinary purgative properties of sulphate of soda, sulphate of ammonia, and other salts, by "combining" the salt with a molecule of oxygenated water. The peroxides of soda, cadmium, magnesium and zinc, considered to be valuable intestinal antiseptics, act by reason of a proportion of their constitutional oxygen being liberated in the nascent state, on contact with organic tissue, the nascent oxygen destroying the toxines which are the cause of intestinal fermentation. Other elements besides oxygen may be made use of in the nascent state. Sulphur iodide, on account of its easy decomposability and the then nascent state of its constituents, produces a very energetic action, and may be used in stomachic and intestinal fermentation. The communication embodies a new law in therapeutics which will be made use of with profit, in the preparation of drugs more effective than those employed up to the present time.

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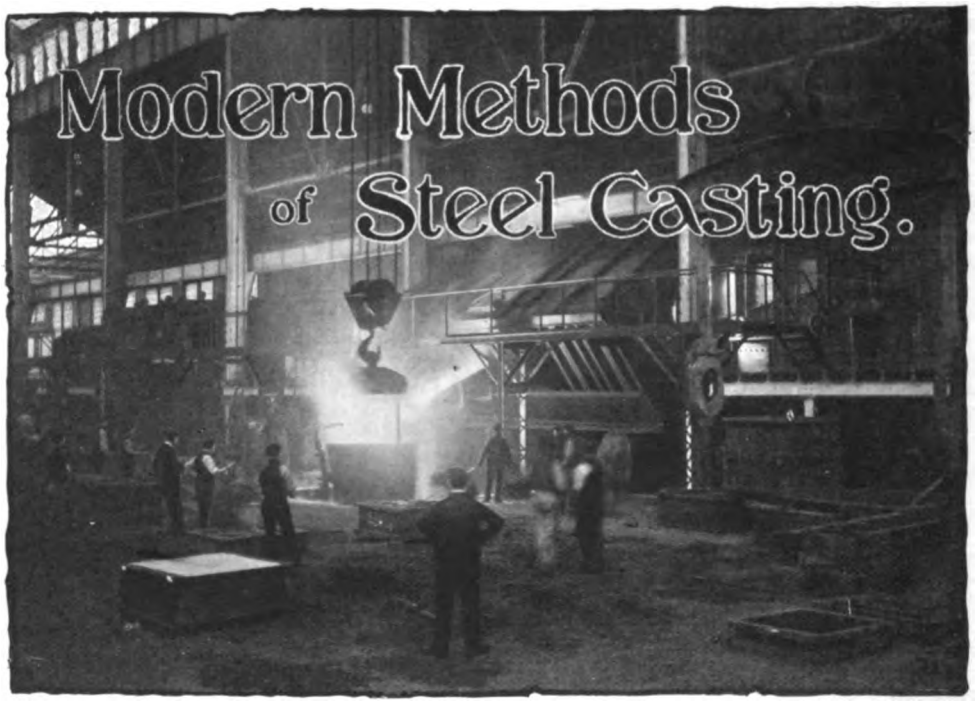

By JOSEPH HORNER, A.M.I. Mech.E.

AT first sight it might appear that the differences between steel and iron would have little effect on the methods of making the two classes of castings. That, however, would be a very incorrect view; for, beyond the work of making the actual moulds, the two methods have little in common. Further, although the actual moulding is done on very similar lines in iron and steel foundries, there are yet important differences which separate steel founding as a craft from iron founding. There are variations in the materials of which the moulds are made: the metal behaves differently, and has to be treated accordingly; and some matters, such as shrinkage, that are common to both, have more pronounced effects in steel, and are much more troublesome to deal with.

The mechanical details of moulding are common to all branches of foundry work, being those which were described in a previous article * in TECHNICS on "Modern Methods of Casting." The steel caster adopts the methods of bedding-in, turning-over, machine-moulding, and the rest. He rams, vents, mends up when necessary, employs cores, uses ingates and runners, dries the moulds, and pours the metal. The mechanical work of steel-moulding differs mainly from that of iron-moulding in the following particulars:—A much larger proportion of steel castings are moulded in dry than in green sand—a necessary precaution on account of the high temperature of the molten steel. Steel moulds are rammed harder than those of iron, for the same reason. To withstand the action of the metal, the facing sands and washes must be more infusible than those used for iron moulds: nearly pure silica is generally used. Tar is sometimes used for blackening. Large drying pits are required in steel foundries for the heaviest moulds, which are made and dried *in situ* when too large to be put into the stove. They are covered over with plates during the drying, which is carried out with gas.

The general employment of steel castings in engineers' work was brought about by the Bessemer process, by which several tons of cheap metal could be produced from molten pig within half an hour. The effect on engineering practice was astonishing. At once firms began to substitute steel castings for those of iron; for gear-wheels especially, and

* See TECHNICS, No. 3, pp. 269-276.

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for those more or less flimsy details of work which had previously been forged, or made in malleable cast iron. Bessemer metal lent itself to the production of shapes which could be forged only with difficulty and expense. The alternative was the use of malleable cast iron, which is not so strong as steel, nor is its range of strength and ductility so great as that which is obtainable in steel. Steel also displaced cast iron for many articles; being much stronger if of similar dimensions, or as strong when made of smaller dimensions, with resulting lessening of the weight of mechanisms. It therefore entered into rivalry with cast iron, malleable iron, and forged work. Later, the electrical industry greatly increased the demand for steel castings.

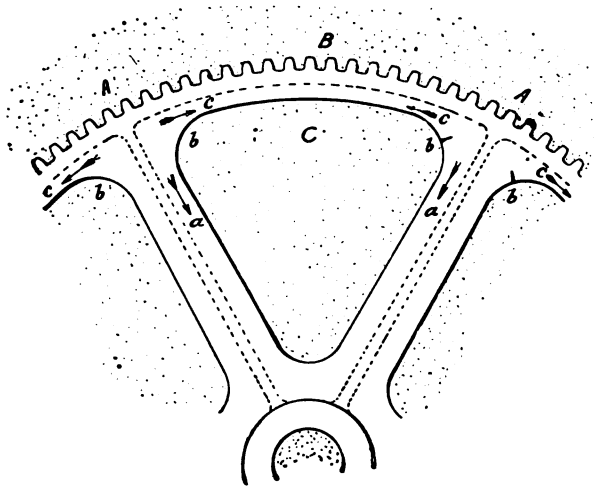

FIG. 1.—ILLUSTRATES THE SHRINKAGE OF A STEEL WHEEL.

Looking back to that period, the immediate results were somewhat disappointing. The early castings were very hard, very much blown, and the effects of shrinkage were in some cases so pronounced as to render them either useless, or to detract greatly from their strength. After much disappointment, improved methods, and a clearer understanding of the problems to be tackled, were arrived at. Let us first consider the important question of shrinkage; for the troubles of steel casting were, and still are, largely due to the excessive shrinkage of the metal, combined with its lack of fluidity: steel setting much more quickly than cast iron does. We use the term "metal" loosely in this article without apology, just as it is employed in the shop sense. All iron, cast or malleable, steel, and brass constitute "metal" to the founder, although these substances are really alloys.

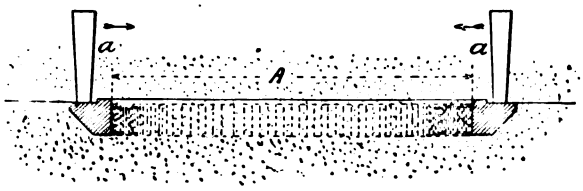

FIG. 2.—LARGE INGATES ON A STEEL CASTING HINDER SHRINKAGE.

Taking shrinkage first: its amount in cast steel varies considerably, depending on the chemical composition, the degree of hardness, and the temperature at which the steel is poured. But it may be taken very approximately at $\frac{1}{4}$ inch to the foot, while that of cast iron is about $\frac{1}{8}$ inch in 2 ft. 6 in. This is not the only feature by which steel is distinguished from cast iron. The shrinkage of brass is half as much again as that of iron, but it does not give trouble. Every ill connected with shrinkage that affects cast iron influences steel in a far greater degree. Matters are complicated by the fact that steel is cast in very hard dried moulds, of which siliceous ganister forms the principal portion; with the result that the castings are tied, and their natural movements impeded. The behaviour of steel when shrinking is well illustrated by the sketches here given, selected from notes made of castings which have passed through the writer's hands at different periods.

The mould for the spur wheel, Fig. 1, selected from several of this form, was, of course, truly circular. But the casting came

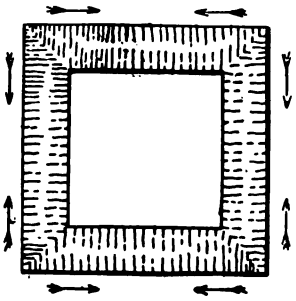

FIG. 3.—ILLUSTRATES WEAKNESS DUE TO LINES OF CLEAVAGE.

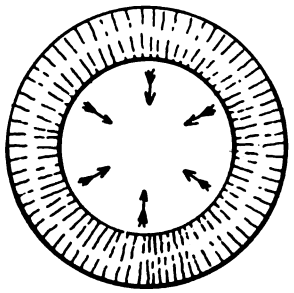

FIG. 4.—THE STRONGEST FORM OF CASTING.

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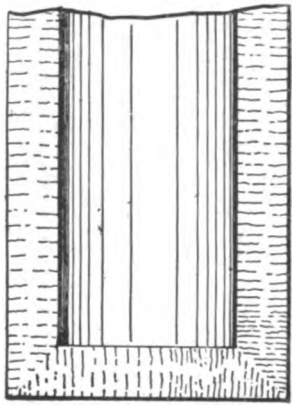

FIG. 5.—A CASTING OF THE WEAKEST FORM.

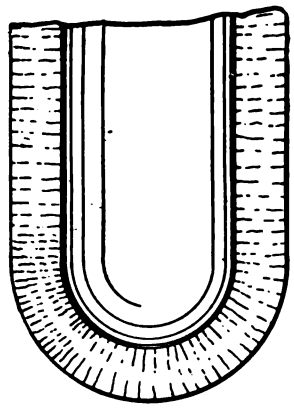

FIG. 6.—A CASTING OF THE STRONGEST FORM.

out smaller in diameter at A, A, in line with the arms, than at B, midway between them. This was due to the inward pull exercised by the shrinking of the arms in the direction indicated by the arrows *a a*. The result of this, in wheels of from 4 feet to 5 feet in diameter, was, that opposite every arm the measurement was less by from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch than that taken across at B. The wheels, therefore, had to be turned on the tips of the teeth to remove a portion of the irregularity. Another evil sometimes happens, to prevent which is the object of the large radii at *b b*; at these places minute cracks, indicated on the right hand, are liable to develop in the castings, due to the pull caused by the shrinkages in the directions of the arrows *a* and *c*. This is got over only by putting very large radii in the corners as shown. The want of circularity in the rims can only be lessened by digging away the sand at C, before the metal has cooled down—an important point to which we shall have to refer again.

The effect of shrinkage, restricted to a portion of a mould, is seen again in the ring of internal teeth used for slewing cranes, Fig. 2, in which *a a* are the ingates, the very large dimensions of which are to be noticed. The sand within these tied them fast, and thus they held the ring fast immediately below. The result was, that several of these rings came out elliptical in form, measuring as much as from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch more in diameter at A than they did in a perpendicular direction. Digging away the sand from the inner portions of the ingates at *a a* before the casting had cooled down to a full cherry red, got over this difficulty.

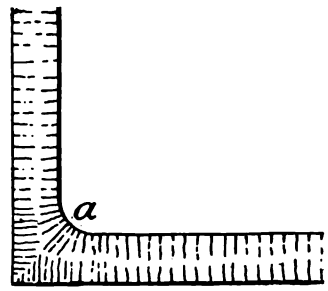

FIG. 7.—A CASTING STRENGTHENED WITH A "FILLET" OR "HOLLOW."

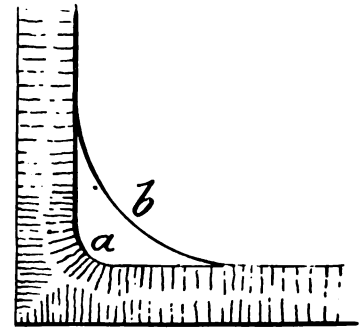

FIG. 8.—A CASTING STRENGTHENED WITH A FILLET AND A BRACKET.

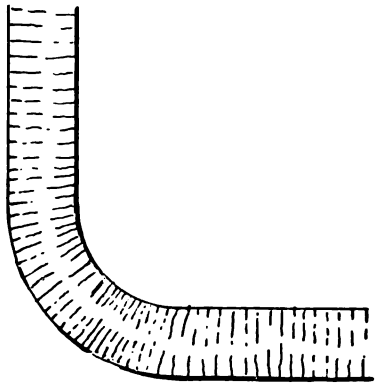

FIG. 9.—CASTING FILLETED AND MOUNTED.

These shrinkage strains cause trouble to the iron founder also, producing distortion, or fracture; or severe internal stress without fracture; but they occur on a smaller scale, and are more easily dealt with. They are of the same character, however, and it will be as well to look into the reasons for their occurrence, and the way to prevent them, or lessen their effects.

The crystals of iron and steel, in cooling, arrange themselves with their longer axes at right angles to the external faces of the metal. It is not difficult, therefore, to tell beforehand where the lines of separation, or cleavage of the crystals, must occur.

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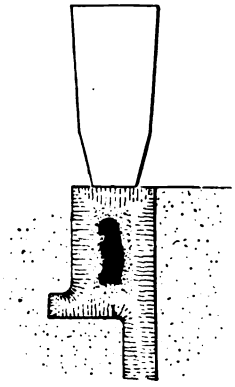

FIG. 10.—A BAD "DRAW" IN THICK METAL.

On comparing a square frame, Fig. 3, with a circular one, Fig. 4, we see at once that the first is the weakest, and the second the strongest possible form of casting. The shrinkage of the sides of the first tends to widen the natural lines of cleavage between the crystals: that of the second reduces the diameter, and the crystals are simply rendered more compact. Figs. 5 and 6 are forms derived from 3 and 4 respectively, and have their applications in daily practice. To strengthen a section like

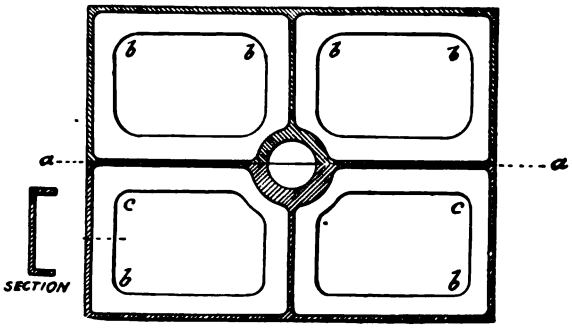

FIG. 11.—AN ENCLOSED FRAME, PROPORTIONED FOR STEEL AND FOR IRON.

There is another matter inseparably related to shrinkage and crystallisation, and one which is of equal importance. It is the "drawing" of metal under shrinkage: meaning by this, the pull exercised on interior masses in heavy sections, by the shrinkage of the external parts.

In Fig. 10 we have adjacent heavy and light sections, and whether cast in iron or in steel, the central portions of the heavier section will be "drawn," and be more open than the outer parts; it will frequently be found, on fracture, to be actually destitute of metal, as indicated. To avoid this, care is taken to maintain a supply of molten metal to the thick parts during shrinkage, by sinking heads, by feeding, and by pouring fresh metal into the runner as the cooling proceeds.

These draws can be foreseen, though it is often difficult to avoid them. Invariably the interior portions of any casting (except the very thinnest, say below $\frac{5}{8}$ inch or so in thickness) show on fracture larger and coarser crystallisation about the central

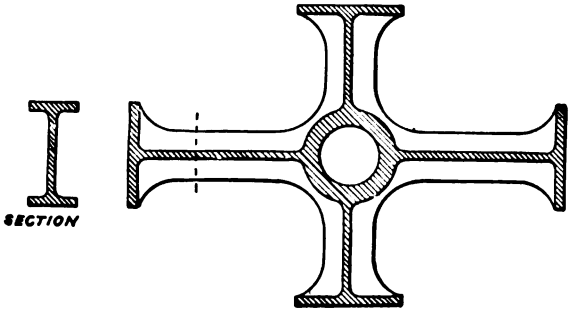

FIG. 12.—AN OPEN FRAME, EASILY CAST.

Figs. 3 and 5 is the object of inserting curves or fillets (Figs. 7 and 8, *a*), or of brackets (Fig. 8, *b*); these play a most indispensable part in the design of castings, both in iron and steel, but especially in the latter substance. The curve *a* obliterates a portion of the sharp lines of cleavage; and though *b* does not change the crystallisation, it strengthens an otherwise weak section. The ideal section is that shown in Fig. 9, so that a nicely filleted and rounded casting is not merely an æsthetic object, but something entirely utilitarian in character.

Of what value are calculations as to the strength of castings that are based only on careful tests, worked perhaps to several places of decimals, when bad designs can bring the castings within an ace of breaking? Sometimes castings will fracture in frosty weather from this cause alone, besides failing under test loads,

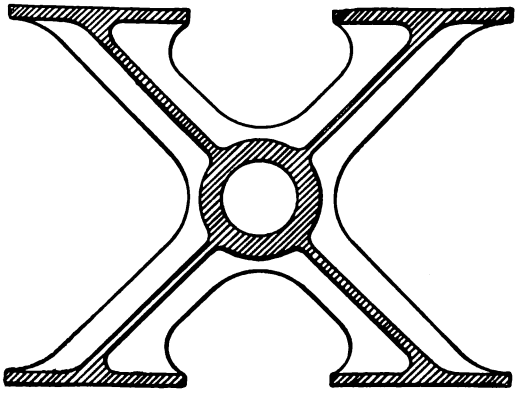

FIG. 13.—AN OPEN FRAME, EASILY CAST.

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portions than next the exterior. The explanation is, that the inner crystals, cooling slowly, become subject to the pull of those which have already set; when they cannot yield any farther, they part company, leaving central spaces open, as in Fig. 10. If a casting is of similar substance throughout, little or no trouble will arise, because the entire mass will cool more uniformly. It is, of course, impossible to embody uniformity of section, or of mass, in all castings; but the aim must be to approximate thereto as closely as practicable.

We are now in a position to consider some other examples of castings. Fig. 11 illustrates the centre bed of a crane, which, if cast in steel in the proportions shown below the line *a a*, would either fracture, in consequence of the shrinkage of the heavy boss, or be pulled

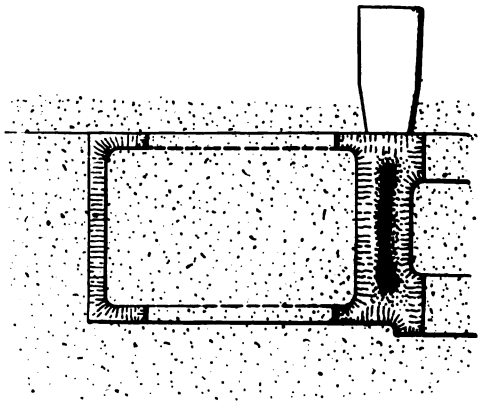

FIG. 14.—HEAVY BOSS, WITH A BAD "DRAW" IN THE CENTRE.

concave along the sides, or crack at the angles *b* or *c*; or all these things might happen. But if the sides, which act as ties, are taken away, and the casting is made as in Fig. 12, or of the modified shape in Fig. 13, then, since there is nothing to act in opposition to shrinkage, the casting will remain sound, and will suffer little distortion.

The lower half of the illustration in Fig. 11, which shows a design suitable for iron, can, if modified as in the upper half, be cast in steel. The differences are, that the mass of the boss is much lessened for steel, and that larger radii are arranged in the angles at *b*. A heavy boss in steel (and in a lesser degree, too, in iron), would either increase the distortion of the casting, or help to produce fracture at *b*; while the interior would be honeycombed and open, as in Fig. 14.

The reason why a big boss causes fracture, and itself remains open and spongy in the central portions, should be clear from what has been already stated. The thinnest parts of a casting, and the outer faces which are in contact with the sand, are the first to cool. These cooled portions, being set rigidly, cannot accommodate themselves to the shrinkage which is going on in adjacent portions. In Figs. 11 and 14, therefore, the comparatively thin webs of the ribs and flanges cool long before the mass of the boss does. The walls of the boss also cool before the interior does. And thus the boss continues to shrink away from the rigid arms, and its interior also shrinks away from its outer faces, so that what will occur is fracture at *b b* (Fig. 11): sponginess in the boss (Fig. 14); and cracks at all the angles of the framing, unless prevented by modifying the shape as seen above, *a a*, for steel.

An enclosed bed or framing like Fig. 11, but having diagonal ribbing like that in Fig. 13, is even more troublesome to cast than one with ribbing at right angles; for in addition to the shrinkage pull of the metal per foot of length, there is the increased length on which it is exercised, due to the diagonal direction of the bars. Such castings not only give trouble from this cause, but also from the massing of the metal in the corners, where the diagonals meet the sides. Drawing occurs here, in addition to the risk of fracture, as indicated in Fig. 15. This makes a dangerous section, and the metal in the corner will certainly be strained by the pull of the diagonal rib, and will be spongy or open internally.

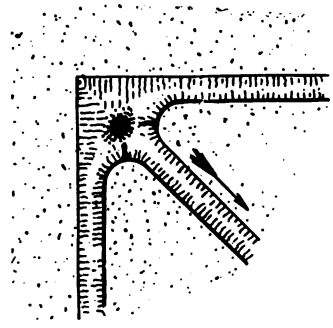

FIG. 15.—INJURIOUS THICKENING OF METAL, LIABLE TO PRODUCE A "DRAW" AND INCIPIENT FRACTURE.

It might be inferred from the foregoing that there would be no difficulty in making steel castings in which the metal is uniformly thin. But that depends entirely on the shapes required. Provided there is nothing to interfere with shrinkage, as in Figs. 12 and 13, such castings are safely made. But cores interfere greatly with shrinkage, and therefore cannot be cast without risk.

(To be continued.)

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THE SHRINKAGE AND WARPING OF TIMBER.

By HAROLD BUSBRIDGE, A.R.C.Sc., A.R.I.B.A., Mem. San. Inst.

IT is well known that timber, in drying, is apt to shrink, and it is commonly supposed that inferior timber is more liable to this defect than timber of good quality.

Although some woods shrink more than others, the fact remains that in all kinds of timber, some amount of

FIG. 1.

shrinkage is bound to occur. All that can be done is to cut the timber in such a way that it can shrink freely without giving rise to splits, cracks, and that curvature of the pieces known as "warping."

As soon as a tree is felled, its natural moisture begins to evaporate, and since evaporation can only take place from surfaces exposed to the air, the exterior of the log becomes much drier than the interior.

The driest parts of wood naturally shrink more than the other parts, hence the ends of logs and baulks generally become full of cracks or shakes, owing to their getting dry more quickly than the interior. In order to avoid these end shakes as much as possible, timber merchants often nail strips of wood across the ends of valuable boards of hardwood, as a protection from wind and sun. The evaporation of moisture being thus retarded, the shrinkage takes place more uniformly throughout the piece, and the tendency to cracking is reduced.

In order to obtain comparative results as to the behaviour of the same wood when treated in different ways, a set of specimens was taken from a cherry tree of about twenty years' growth. Sections about $1\frac{1}{4}$ inch thick were sawn successively from the butt end of the tree, immediately after felling; and after being cut in various ways, as shown in the illustrations, were all placed together in a dry cupboard and allowed to shrink, warp or split, at will.

By taking their weight when first cut (in June) and comparing this with their weight when thoroughly air-dried about nine years after, it was found that the ratio of their weight when wet to the weight when dry was 1·63. It is probable that the driest wood exposed to air under ordinary conditions never contains less than 5% of moisture; therefore on this assumption, it appears that the cherry wood in question originally contained at least 72% of water.

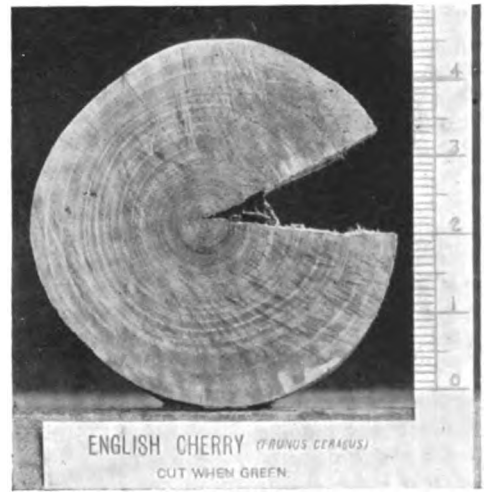

FIG. 2.

The section shown in Fig. 1 was left with the bark upon it, and since evaporation could not take place from its outer surface so freely as from the section (No. 2) which was stripped, the radiating splits have not opened to so wide an angle. In No. 2 the whole of the shrinkage

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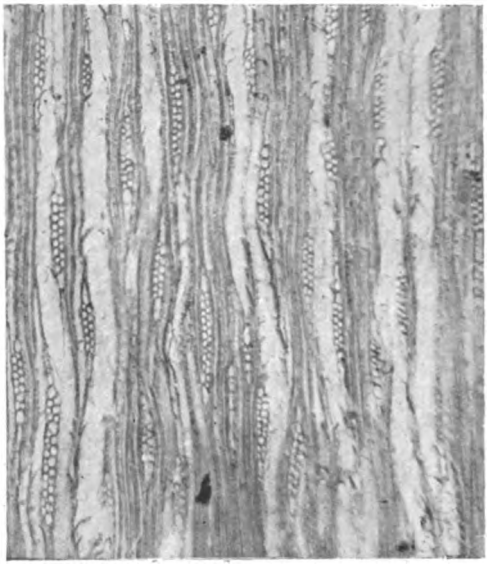

FIG. 3.—BOXWOOD: TRANSVERSE SECTION.

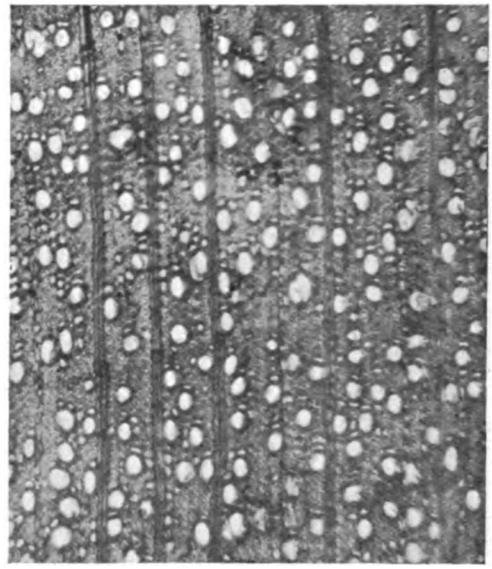

FIG. 4.—BOXWOOD: TANGENTIAL SECTION.

being collected into one angular split, it is at once evident that the shrinkage in a tangential or circumferential direction is greater than tnat in a radial direction. It is well known that all woods shrink very slightly indeed in a longitudinal or axial direction, and from our observations it appears that the tangential is greatly in excess of the radial shrinkage. In seeking for an explanation of this, we are led to study the microscopic structure of wood.

We soon find that certain definite characteristics mark the structure of all timbers, although each kind has its own peculiarities. Broadly speaking, the mass of all wood is chiefly made up of capillary vessels of various kinds, running in a vertical or axial direction; some large, but the greater number being small in diameter. The space occupied by the walls of these vessels bears but a small proportion to the air space enclosed by them; hence the large capacity for water which most soft woods possess. Besides the vertical members known as vessels, tracheides, and wood fibres, all woods exhibit groups of elements known as parenchymatous cells intersecting the former set, at intervals, in radial vertical planes. These are often visible to the naked eye, and form what are known in oak and other hard woods, as "medullary rays," the annual rings being formed by the vertical elements already referred to.

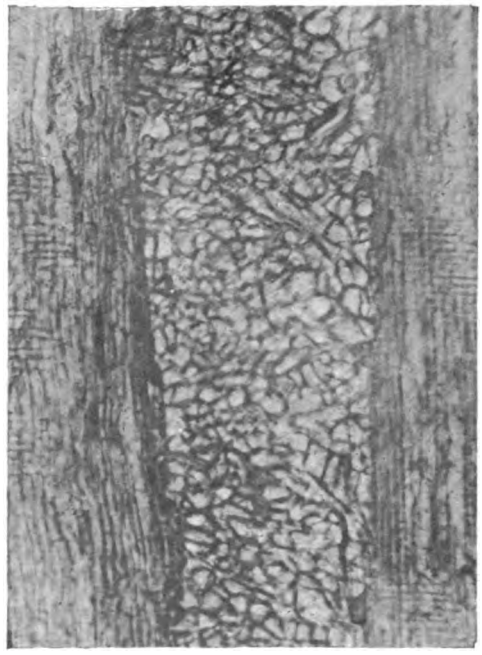

FIG. 5.
BOXWOOD—RADIAL SECTION.

It appears that each individual cell, whether running in an axial or a radial direction, has little or no tendency to alter its *length* in drying, but that all alike have a strong tendency to contract in *diameter*; although probably the different kinds of cells differ in degree as to their contraction, according to their size, and the relative thickness of their cell

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walls. Any given segment of wood, bounded by vertical planes radiating from the centre of the tree, will therefore consist chiefly of vertical cells which have no tendency to change their length, but which will contract in diameter, either in a radial or tangential direction. It also contains a relatively small number of horizontal cells radiating from the axis, which resist any contraction in a radial direction, but which freely contract in a tangential direction.

It is evident, therefore, that, as with a lady's fan, change of dimension will take place most freely in a circumferential or tangential direction, and this affords a key to the interpretation of the forms assumed by the pieces of cherry wood here represented.

The three micro-sections of boxwood given in Figs. 3, 4 and 5 are fairly typical in character, and show clearly the structure of the medullary rays.

Fig. 6 shows that by sawing a log down the centre immediately after felling, the radial splitting may be largely avoided; but that the two plane faces become convex in seasoning, this defect being less injurious to the timber than irregular splits.

Fig. 7 demonstrates that logs when "quartered" give timber which is still more free

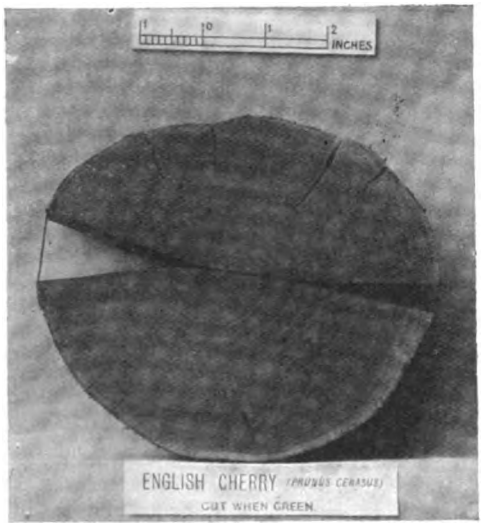

FIG. 6.

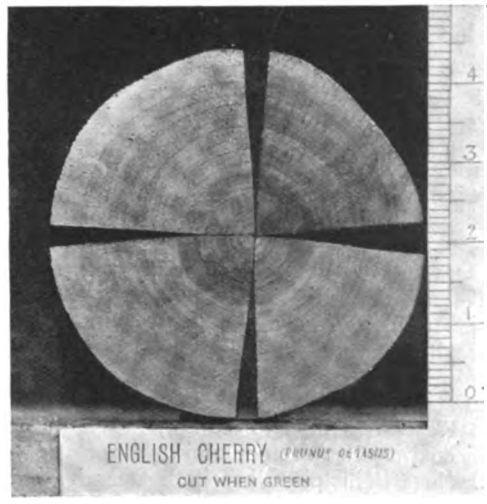

FIG. 7

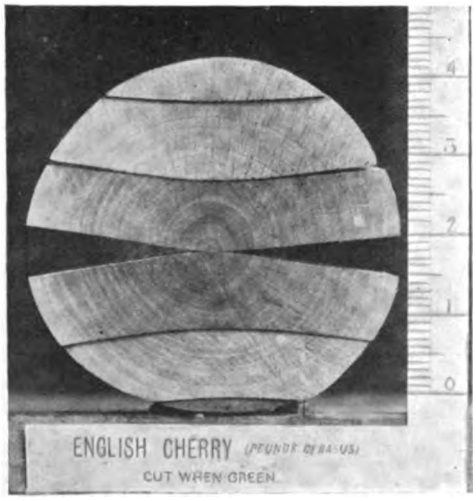

FIG. 8

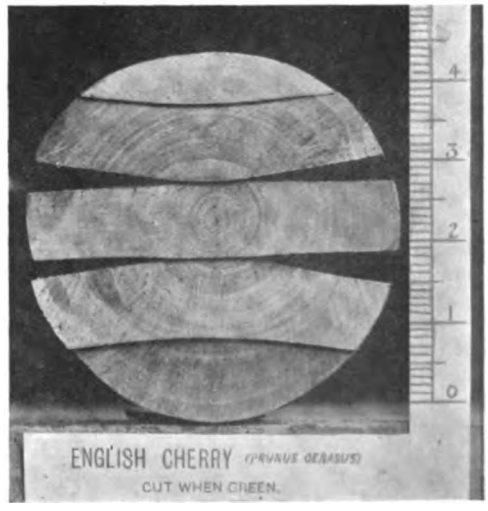

FIG. 9.

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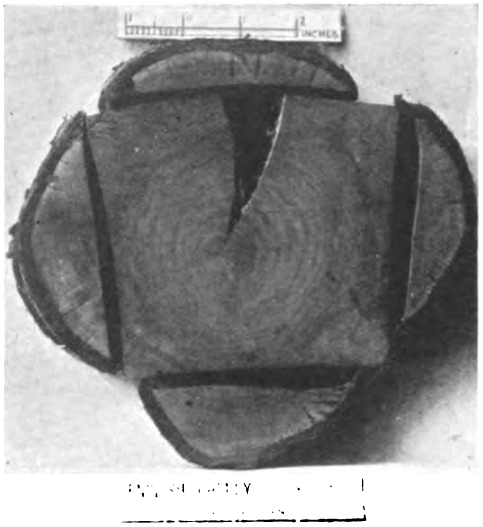

FIG. 10.

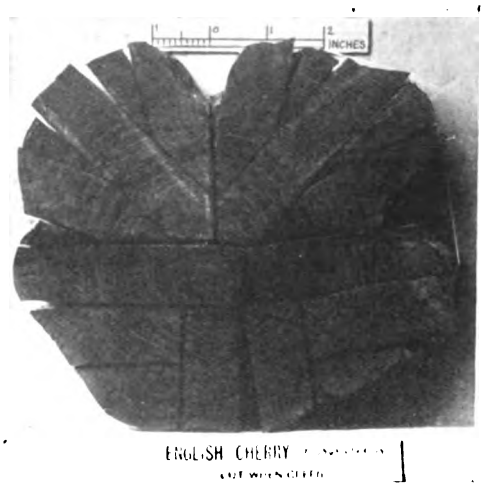

FIG. 11.

from splits than when halved, as the inevitable shrinkage can take place more easily.

In Fig. 8 is seen the effect of cutting off planks or boards after first halving the log. Here each plank must shrink more on that side farthest from the heart, and hence the result is a curved plank, having its concave side turned away from the centre of the tree.

Fig. 9 is similar to the last, except that a piece was first cut containing the centre of the log. This piece has both faces convex, and shows clearly that the shrinkage near its edges, which contain the sapwood, is much greater than that around the centre which consists of heartwood.

Fig. 10 exhibits the evils consequent upon the conversion of timber into *baulk*, *viz.*, that shakes generally run from near the centre or one or more faces towards the heart. In this case, instead of getting several small shakes in each face, as is usual, the whole amount of shrinkage is collected into one large split.

Fig. 11 illustrates a method sometimes practised in cutting up large logs, so as to reduce the splitting and warping tendency to a minimum. Each piece has been able to shrink without restraint, hence there is little or no warping and splitting.

Messrs. Newton and Co. stock a series of lantern slides, prepared by Mr. Busbridge, including Figs. 1, 2, 6, 7, 8, 9, 10, 11 *in the article.*

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THE MECHANICS OF THE GYROSCOPE.

By Dr. S. TOLVER PRESTON.

WHILE the gyroscope affords a notable illustration of the harmony amongst physical laws, the elementary exposition of the principles governing its action does not seem to have received the attention it deserves.

Professor Perry's interesting work,* entitled "Spinning Tops," contains little more than rules for ascertaining what will happen under given conditions, together with striking experimental illustrations, and applications to cosmical phenomena, such as those connected with the rotation of the earth and other planets.

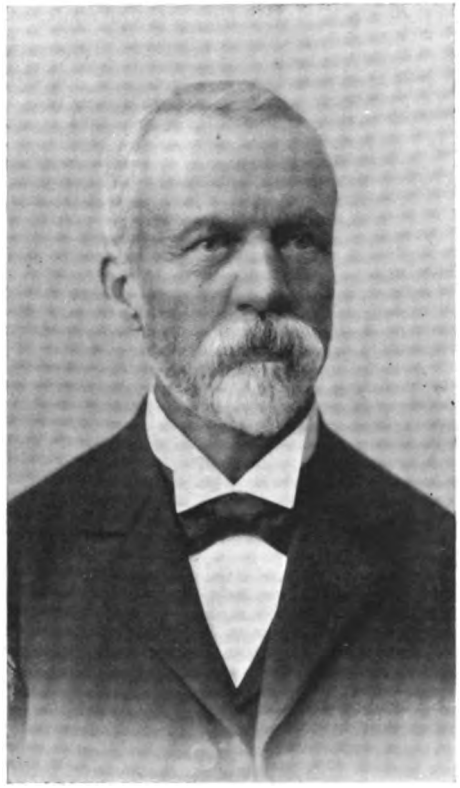

Photo by [*Julius Wölken.*

DR. S. TOLVER PRESTON.

It is superfluous to dwell at length on the practical importance of the subject, since rotation is one of the most general motions produced in machinery. The most recent theories of molecular structure also involve the orbital motions of atoms and electrons; so that, from the atom to the solar system, we are continually confronted with problems dealing with rotations and revolutions. On the other hand, text-books afford no adequate elementary treatment of this subject. I have therefore been reduced to think out an elucidation for myself, which I venture to present here.

According to the Newtonian system of dynamics (a system which is now universally recognised and accepted), the velocity of a particle can only be increased in any given direction by the application of a force acting in that direction; conversely, its velocity in a given direction can only be diminished by the application of a force acting in an opposite direction. The magnitude of the applied force is proportional to the rate of increase or decrease of the velocity of the particle.

Let us suppose that a series of equal heavy particles are arranged around the circumference of the circle in Fig. 1. These particles may be supposed to be rigidly connected one with another, the whole being connected by massless spokes, with an axle passing through C, the centre of the circle; this axle being at right angles to the plane of the paper. This arrangement constitutes an ideal fly-wheel, and may be considered as typical of an ordinary gyroscope disc.

Let the fly-wheel be set in rotation in the direction indicated by the arrow. The problem before us is to determine the nature of the forces which must be applied to the rotating fly-wheel in order to deviate the axis of rotation. Let us suppose that the fly-

* "Spinning Tops." By Professor J. Perry, F.R.S., etc., 1901 (Society for Promoting Christian Knowledge, 43, Queen Victoria Street, E.C.).

This book is based on the "Operatives Lecture" delivered before the British Association in 1890. To my mind it appears that even a general audience of "Operatives" would have been quite capable of grasping and appreciating far more of the elementary elucidation than was offered in connection with this fundamentally practical branch of mechanics. The field for the exercise of the powers of the scientific imagination becomes wider, in proportion as elementary methods of exposition are extended.

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wheel, while still rotating about its axle, is constrained in addition to turn about the line A B, at right angles to the axle. Looking in the direction A B, let the fly-wheel turn about that line in a clock-wise direction, so that the side L moves downwards through the plane of the paper, while the side R moves upwards through the same plane. The particles at *e* and *p* being, at the given instant, on the axis of rotation A B, will possess no velocity of rotation about that axis. So far as concerns other particles, their velocities of rotation about A B will

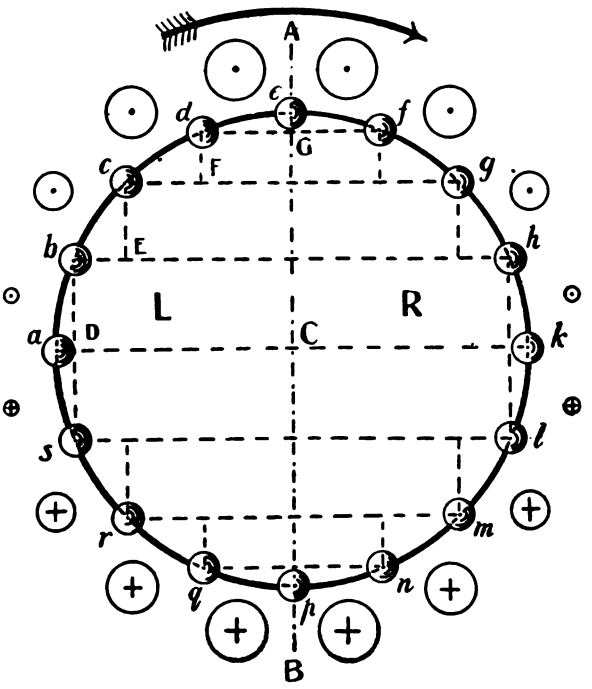

FIG. 1.

be proportional to their perpendicular distances from that line. Sixteen equidistant particles on the circumference of the circle have been indicated. The rotational velocities of these particles, about the line A B, will be proportional to the respective perpendiculars let fall on A B.

In a certain interval of time the disc will complete a revolution about its axle. In one-sixteenth of this interval of time, the particle *a* will move round the circle so as to attain the position previously occupied by the particle *b*. In doing so, the particle *a* will acquire the velocity previously possessed by the particle *b*; *i.e.*, its velocity will be diminished, since *b* is nearer than *a* to the axis A B. The diminution of velocity will of course be proportional to *a* D, where *b* D is a line drawn from *b* perpendicular to C *a*. But since the velocity of the particle *a*, in a direction passing vertically downwards through the plane of the paper, is diminished as the particle moves from *a* to *b*, this particle must have been acted upon by a force directed *vertically upwards* through the plane of the paper, and proportional to *a* D. This force is indicated by a small circle containing a dot at its centre. The dot indicates the pointed end of an arrow supposed to be directed vertically upwards through the paper; while the diameter of the small circle is drawn proportional to *a* D, or to the magnitude of the force.

While the particle *a* moved to *b*, the particle *b* moved to *c*. In this time the velocity of the particle *b*, perpendicular to the plane of the paper, must have been diminished by an amount proportional to *b* E. A small circle containing a dot at its centre, and of a diameter proportional to *b* E, indicates the magnitude and direction of the force which must have been applied to the particle as it moved from *b* to *c*.

The force which acted on the particle *c* as it moved to *d*, and that which acted on the particle *d* as it moved to *e*, are represented in a similar manner.

Owing to the rotation about the line A B, all particles on the right-hand side of the disc are moving upwards through the plane of the paper; thus it follows that the particle *e*, in moving to the position *f*, must have acquired a velocity, directed vertically upwards through the paper, proportional to G*f*. It must, therefore, have been acted upon by a force, proportional to G*f*, directed vertically upwards through the paper. The forces acting on the particles *f*, *g*, *h*, can be determined in a similar manner.

It is obvious that the velocity of the particle *k*, directed upwards through the plane of the paper, is diminished as that particle moves to the position previously occupied by the particle *l*. Consequently, it must have been acted upon by a force, of which the magnitude is determined in the manner previously explained, acting *downwards* through the plane of the paper. A circle, of which the diameter is proportional to this force, while the cross at its centre represents the feathered

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end of an arrow directed downwards through the paper, indicates the magnitude and direction of the force acting on the particle *k* as it moved to *l*. The forces acting on the particles *l*, *m*, *n*, *p*, *q*, *r*, *s*, are determined similarly, and represented by circles containing crosses, to indicate that the forces act downwards through the plane of the paper.

A glance at Fig. 1 shows that all forces acting on the part of the fly-wheel above the line *a k*, are directed upwards through the plane of the paper; while all forces acting on the part of the fly-wheel below the line *a k*, are directed downwards through the plane of the paper. All the forces acting above the line *a k* might be replaced by a single resultant force, acting upwards through the paper at some point on the line C *e*; while all the forces acting below the line *a k* might be replaced by a single resultant acting downwards through the paper at some point in the line C *p*. These two resultant forces, acting parallel to each other, but in opposite directions, constitute a couple, and produce a *torque* or *turning moment* about the line *a k*. Thus, in order to turn the revolving fly-wheel about the diameter *e p*, we must apply a torque which, if it acted on the *stationary* fly-wheel, would turn it about the perpendicular diameter *a k*. Conversely, if we apply a torque tending to turn the fly-wheel about a diameter *a k*, it will turn, not about *a k* (as might have been expected), but about the perpendicular diameter *e p*.

The torque necessary to deflect the fly-wheel might be produced by forces acting directly upon it, as for instance, by blowing air on the upper half of the fly-wheel from the back, and on the lower half from the front. Generally, however, it is more convenient to act on the axle, the end above the plane of the paper being urged in the direction C B, while the end below the plane of the paper is urged, by an equal force, in the direction C A.

Some further points should be noted. Any force acting to the right of the line A B, is equal, both in magnitude and direction, to a corresponding force acting to the left of the same line. Consequently, as the fly-wheel turns about the axis A B, no work will be performed by the forces producing this rotation. This follows from the circumstance that whereas one force acts in the direction of motion (so far as relates to rotation about the axis A B) the other equal force is opposed to that motion.

The actual behaviour of a gyroscope can now be easily understood. The fly-wheel *a a* (Fig. 2) having been set in rapid rotation in the direction indicated by the arrow *r*, the frame carrying it is supported from a projection *n* at one end, on a pivot *o*. Instead of falling to the ground, as it would do if it were not rotating, the gyroscope remains with its axis *b z* horizontal; but the axis turns in a horizontal plane about the point of support *o*, in the direction indicated by the arrow *s*. The torque produced by the pull of gravity is easily seen to be that required to turn the fly-wheel *a a* about a vertical diameter in the direction mentioned. The fact that the fly-wheel, besides rotating about a vertical axis, also revolves in a circle about the point *o* as centre, is merely due to the circumstance that, under the conditions of the experiment, the rotation cannot occur without the revolution.

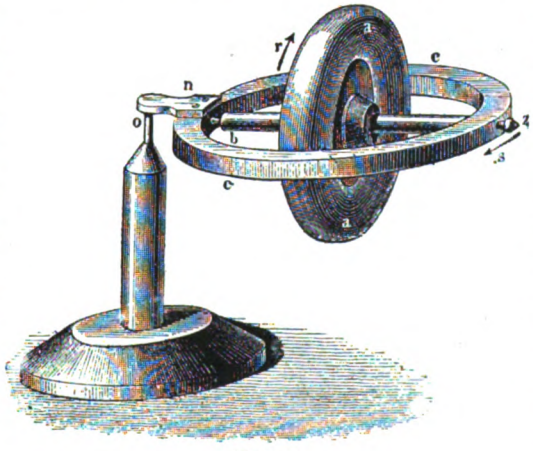

FIG. 2.

It is instructive to consider the same problem from a somewhat different standpoint. We have already determined the nature of the *applied forces* required to turn the ideal rotating fly-wheel (Fig. 1) about the axis A B, in a clockwise direction when viewed from A. We found that a torque must be applied which tends to urge the end of the axle above the plane of the paper in the direction C B, and the opposite end of the axle in the direction C A. It will now be proved that the *reaction* of the rotating fly-wheel, when it turns as above, about the axis A B, produces a torque which tends to urge the end of the axle above the plane of the paper in the direction

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C A, and the other end of the axle in the direction C B.

Under the given conditions, the component velocities, downwards through the plane of the paper, of the particles *a*, *b*, *c*, *d*, are all being diminished; and the consequent reactions tend to turn the axle in a clockwise direction, about the line *k a*, when viewed from the side *k*. The component velocities, upwards through the plane of the paper, of the particles *e*, *f*, *g*, *h*, are all being increased, and the consequent reactions tend to turn the axle in the same direction. It is easily seen that the reactions due to the alterations in the velocities of the particles *k*, *l*, *m*, *n*, *p*, *q*, *r*, *s*, all tend to turn the axle of the fly-wheel in the same direction. Thus the torque due to the reaction of the rotating fly-wheel when turning about the axis A B, is of the character specified above.

The precise way in which the gyroscope (Fig. 2) acts can now be readily followed. When the frame carrying the rotating fly-wheel *a a* is first supported on the pivot *o*, the initial tendency is for the whole to descend toward the earth, under the action of gravity. But the pivot *o* prevents the end *b* of the axle from descending, so that an incipient rotation about a horizontal diameter commences. The reaction due to this rotation produces a torque which tends to turn the fly-wheel about a vertical diameter in the direction of the arrow *s*. As the fly-wheel is free to turn in this direction, it at once commences to do so, and in so doing generates a reacting torque opposing the incipient rotation produced by gravity. The action of gravity being opposed, the rate of (incipient) descent of the fly-wheel is diminished; but so long as descent continues, a torque acting in the direction of the arrow *s* will be produced, and this will increase the velocity of turning, thus increasing the torque which opposes the descent of the fly-wheel under the action of gravity. The fly-wheel, finally, acquires a rotational velocity in the direction of the arrow *s*, which produces a reacting torque just equal and opposite to that due to the pull of gravity. If friction were entirely absent, the fly-wheel would then cease to descend, and would continue to turn at a uniform rate in the direction of the arrow *s*. In this process, the work performed is that due to the incipient descent of the fly-wheel; this work is just sufficient to supply the kinetic energy due to the rotation of the fly-wheel and its supporting framework about the axis *o*. When the permanent condition outlined above has been attained, no further work is done in the absence of friction. If there is friction between the supporting lug *n*, and the pivot *o*, the gyroscope will slowly descend, at such a rate that the work performed by gravity is just equal to that needed to ovecome the frictional drag.

In the absence of friction, it is obvious that the gyroscope turns about *o* as centre merely by virtue of its own inertia, after the final state has been reached; in this respect the motion resembles that of a planet around the sun. The torque due to gravity, though necessary, only serves the purpose of neutralising the reacting torque which the turning of the fly-wheel about a vertical diameter produces.

When the gyroscope (Fig. 2), instead of being capable of rotation in a horizontal plane about *o* as centre, is hinged at *o*, so that it can move only in a *vertical* plane, it descends at once toward the earth, no difference being produced whether the fly-wheel is rotating or quiescent. In this case, since turning about a vertical axis is prevented, the gyroscope cannot generate a torque opposed to that due to the pull of gravity.

It is plain that when we attempt to turn a rotating fly-wheel about a diameter, no *resistance* is offered; but a torque is produced, tending to turn the fly-wheel about a perpendicular diameter; and unless this torque is neutralised by another of equal but opposite value, motion in a direction other than that required will occur.

Professor Perry, in one experiment, enclosed a fly-wheel in a box, which served as a convenient means of supporting the ends of the axis of the fly-wheel, without risk of interfering with its rotational velocity. He remarks on the effects observed as follows:—

"When I hold this box in my hands, I find that if I move it with a motion of mere translation in any direction, it feels just as it would do if its contents were at rest; but if I try to turn it in my hands, I find the most curious great resistance to such motion. The result is that when you hold this in your hands, its readiness to move so long as it is not turned round, and its great resistance to turning round, and its unexpected tendency to turn in a different way from that in which you try to turn it, give one the most uncanny sensations. It seems almost as if an invisible being had hold of the box and exercised forces capriciously. And, indeed, there is a spiritual being inside, what the algebraic people call an impossible quantity, what other mathematicians call 'an operator'" (*Spinning Tops*, pp. 21–23).

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I shall not presume to criticise the last sentence; but the mention of "great resistance to turning round" appears capable of an ambiguous interpretation. It has already been pointed out that if a torque tends to rotate the fly-wheel about a diameter as axis, then the fly-wheel will actually turn about a perpendicular diameter as axis. It has also been proved that the forces acting on the fly-wheel do no work; it therefore follows that no *true* resistance is encountered, for motion against a resistance would entail a loss of energy. A given torque produces rotation in a direction that would not be anticipated from experience with non-rotating bodies; but the actual motion produced is exactly that to be predicted from a consideration of the problem from the standpoint of Newton's laws of motion. Thus the gyroscope, while apparently defying gravity, is really acting in accordance with accepted mechanical principles.

The movement of the axis of a revolving gyroscope-disc, at right angles to the disturbing force, is a fact familiar to experimenters. That this movement, at right angles to the direction of the force, is a consequence independently and directly deducible from the accepted law of the conservation of energy, is not so generally recognised.

Let us consider the very simplest instance of a gyroscope-disc, which, of course, is nothing more than a revolving fly-wheel enclosed in a case or box, as one sees in some familiar experimental illustrations depicted in text-books. The case or box then serves merely the purpose of a convenient frame to support the ends of the axis of the fly-wheel.

Now, we know that when the case is rotated by hand, so as to deflect the axis of the fly-wheel, a curious sensation of resistance is felt, when the fly-wheel at the same time *revolves* on its own axis.

Imagine there to be no friction, so that in our experimental illustration the velocity of the fly-wheel remains uniform. Suppose, further, the case or box to be connected with some convenient mechanism which produces the required rotation, thus deviating the axis of revolution of the enclosed fly-wheel, or producing more complicated movements if required: this mechanism being driven by any convenient motor. The enclosed fly-wheel can, of course, run independently on its own axis.

Friction in the mechanism is to be neglected; it can, if necessary, be taken into account or allowed for afterwards. Ideal conceptions, such as where friction is neglected, are recognised as useful for the illustration of truths, and are quite legitimate, provided the essential conclusions are afterwards slightly modified so as to fit exactly with the facts existing in Nature. The "perfect gas," for instance, constitutes a familiar theoretical ideal for deducing the essential truths about actual gases.

Provided that the fly-wheel is not revolving on its axis, and neglecting friction, everyone will concede that no work will be performed by the motor in rotating the box. This is tolerably self-evident. But it may not, possibly, be admitted as equally obvious, that no work will be performed by the motor in effecting deviations of the axis of the revolving fly-wheel.

Yet it appears that the theoretical conclusion as to the absence of work in this process, together with the correlated inference that special stresses, generated during the effected deviations of the axis of the revolving fly-wheel, are never in the resultant *opposed* to the applied forces which produce the deflections of the axis—are both independently deducible, as a simple consequence of the law of the conservation of energy.

(1) When the fly-wheel does *not* revolve, and the motor, deviating the axis in diverse directions, is started, we have a fly-wheel possessing unchanged rotational velocity (velocity equal to *zero*, that is) *before* and *after* the experiment, with nothing to show in the shape of work performed by the impelling motor—neglecting, of course, friction, as agreed. And clearly, under these conditions, no work is really done by the motor.

(2) When the fly-wheel *does* revolve on its own axis, and the motor (variously deviating the axis of the rotating fly-wheel) is put in action, we still have unchanged conditions *before* and *after* the experiment, in that the fly-wheel possesses unchanged rotational velocity.

For it is an accepted fact that no mere deviation of the axis of a revolving fly-wheel can alter its velocity of revolution on its own axis. To recognise this fact without difficulty, we have only to imagine the axis to be indefinitely thin, or, if we like, a mathematical straight line; in which case no torque or "couple" could act on such an axis in order to accelerate or retard the connected fly-wheel, since a couple or torque cannot possibly act without a radius of action. And the theory of the gyroscope or revolving fly-

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wheel is, as an accepted fact, independent of the thickness of the axis of revolution.

Accordingly we have, before and after our two experiments, a fly-wheel revolving on its axis with unchanged velocity. The conditions prevailing before the experiments have remained unaltered, while no more work is demanded in order merely to deviate the axis than would be demanded if the fly-wheel were not revolving; accordingly the inference is, that no work is performed either in experiment (1) or in experiment (2); that is, whether the fly-wheel revolves or not during the deviation of its axis.

How, then, can we account for the "curious resistance," apparently encountered when the axis of a revolving fly-wheel or gyroscope disc is deviated by hand?

Here a brief excursion into simple elements of physiology may be apt for our purpose. We may observe that, in the particular instance of the human body, a force cannot be sustained, even in the absence of accompanying motion, without the performance of work within the body. Holding out a weight at arm's length gives the *appearance* of external work performed, especially if (in addition) one revolve on one's own axis, without raising the weight higher. To try to burst open a closed door by merely pressing against it, may demand much work *inside* the human frame; but, of course, none is accomplished *outside*. For it may be superfluous to draw attention to the fact, that in order to perform work outside one's self, there must be not only a force, but there must be *motion* against this force. Motion *at right angles* to a force does not constitute work; since the motion is not opposed in that instance.

If we imagine a small satellite, or even meteorite, to be guided round a circular orbit by human agency alone, this would demand *internal* bodily work, possibly very great. But it is known that in this instance no work whatever is really achieved outside the human body. For it is a recognised principle that merely to change the path or the direction of motion of a moving particle (or collection of particles) without acceleration, demands no expenditure of work or energy whatever. The same argument obviously applies to the revolving gyroscope disc or fly-wheel: no expenditure of work or energy is required in order to deviate its axis or plane of revolution, provided the fly-wheel be not accelerated in respect to its rotational velocity about its axis.

When the deviations of the axis of a revolving fly-wheel are effected by hand, the curious resistance experienced is clearly referable to the *transverse* stress which arises in the act of deflecting the axis of a revolving body. This stress being transverse (or laterally directed), cannot *oppose* the deflection; but it is experienced all the same by the hands of the operator, and he may *assume* he has done work, in the absence of due precautions: in other words, this stress may readily convey a deceptive appearance of work accomplished outside one's self.

Owing to the physiological innervation and shortening of muscles, with attendant oxydation, in merely sustaining a stress or force even without movement against it, an expenditure of work or energy *inside* the human frame is entailed, which may, to the sensations, *seem* like outside work performed.

Hence (as a brief summary) it appears to be independently inferable from the law of conservation of energy alone, that, in the resultant, all stresses observed or experienced in deviating the planes of revolution (or the axes) of fly-wheels, turbines, or other rotating machinery (as occurs on board a pitching or rolling ship, or elsewhere) are stresses which entail no work or waste of power on the part of the machinery concerned.

In his appreciated work on "Spinning Tops," Professor Perry makes the following remarks (p. 24):—

"When the fly-wheels of steam engines and dynamo machines and other quick-speed machines are rotating on board ship, you may be quite sure that they offer a greater resistance to the pitching or rolling or turning of the ship, or any other motion which tends to turn their axes in direction, than when they are not rotating."

The foregoing reasoning shows that, far from our being "quite sure" of the resistance to pitching or rolling offered by the revolving fly-wheels, we are led to anticipate that, in ordinary circumstances, such resistance is non-existent or negligible. As, however, Professor Perry's statement embodies a not uncommon error, it may be well to devote a few lines to a careful consideration of what occurs. Let us suppose that the axis of a revolving fly-wheel lies in the direction from stem to stern of a ship. Then, if we exclude the action of friction at the bearings, *rolling* of the ship from side to side will produce no effect on the fly-wheel, and the fly-wheel will therefore offer no resistance.

Turning the ship will turn the fly-wheel

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about a vertical axis. The reaction of the fly-wheel will tend to slightly raise the bows and depress the stern of the ship, or *vice versâ*. This "tilting" of the ship will be of but small extent, and will reach its maximum when the torque producing it is neutralised by the action of gravity tending to reduce the ship to its normal level. While the tilting is increasing (*e.g.*, while the bows are ascending and the stern descending) the reaction of the fly-wheel will produce a *very small* torque opposing the turning of the ship; but so soon as the maximum tilt has been produced (which will occur almost instantaneously) all resistance to the turning of the ship vanishes. For a constant resisting torque to be produced, the ship would have to continually rotate in a vertical plane.

When the ship *pitches*, the fly-wheel rotates about a horizontal diameter perpendicular to the axis of revolution. This rotation will produce a torque tending to deflect the fly-wheel about a vertical axis, and, therefore, to turn the ship to one side or the other. If no turning is produced, there can be no torque to resist the rotation due to the pitching of the ship. This case is strictly analogous to that of the gyroscope, hinged so as to be capable of rotation only in a vertical plane (p. 50). If the ship actually does turn under the action of the fly-wheel, a torque will be produced opposing the motion due to the pitching of the vessel; compare the slow descent of the gyroscope (Fig. 2) when friction at the pivot *o* prevents it from turning freely. In this case, *some* opposition would be offered to the pitching of the ship; but fairly rapid turning would be needful in order to make the opposition appreciable. In actual practice, it appears clear that revolving fly-wheels, etc., on board ship offer no appreciable resistance either to pitching, rolling, or turning.

PHARMACEUTICAL NOTES.

Duties on Imported Chemicals and Drugs

IT is probable that in the near future the clause in the "Customs Consolidation Act," with reference to duty on "articles in the manufacture of which spirit has been used," may be made use of. It is provided in the Act that the rate of duty charged shall be as if the spirit used in the manufacture of the article were itself imported.

Anti-Ferments

E. WEINLAND has shown that the tapeworm secretes an anti-ferment. Fibrin, he finds, is not digested by a pepsin solution, to which a small proportion of a liquid obtained from the tapeworm has been added. He suggests that other parasites, and probably also certain human organic tissues, are protected from the action of ferments by similar means. The anti-ferment from the tapeworm is strong in action, and retains its properties well; they are, however, destroyed by boiling. (*Scient. Amer.*, 90, 227.)

Synthesis of Nicotine

NICOTINE has been synthesised by Pictet and Rotschy by the following series of reactions. Nicotyrine, by the action of iodine in alkaline solution, gave a monoiodnicotyrine; this by reduction, using tin and hydrochloric acid, gave a dihydronicotyrine, converted into a perbromide by bromine; the perbromide by reduction gave inactive nicotine. The inactive nicotine was broken up into its optically active components by the aid of tartaric acid. (*Pharm. Centralh.*, 1903; p. 756.)

"Farnesol:" A new Odorous Substance

IF the oils of cassia or ambrette be saponified and fractionally distilled, and the fraction boiling at 150° to 200° at 20 m.m. pressure be heated for several hours to 125°, under pressure, with an equal weight of benzene and 0·6 of its weight of phthalic anhydride, thence the phthalic acid esters be extracted with alkali, decomposed and distilled in steam, a sesquiterpene alcohol having a Sp. Gr. 0·885, refractive index 1·4888, and boiling under 10 m.m. pressure, between 155° and 165° is obtained. This liquid is odorous and has been named "Farnesol." (*Chem. Zeitung*, 1904, 307.)

Determination of Tartaric Acid

A NEW method by H. Ley (*Pharm. Zeit.*, 49, 149), promises a wide range of utility. The tartaric acid is precipitated by zinc acetate, and the zinc tartrate, which is insoluble in alcohol and acetic acid, and almost insoluble in water, is incinerated and weighed as oxide.

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THE INDICATOR FOR LECTURE DEMONSTRATION.

By H. L. CALLENDAR, M.A., D.C.L., F.R.S.

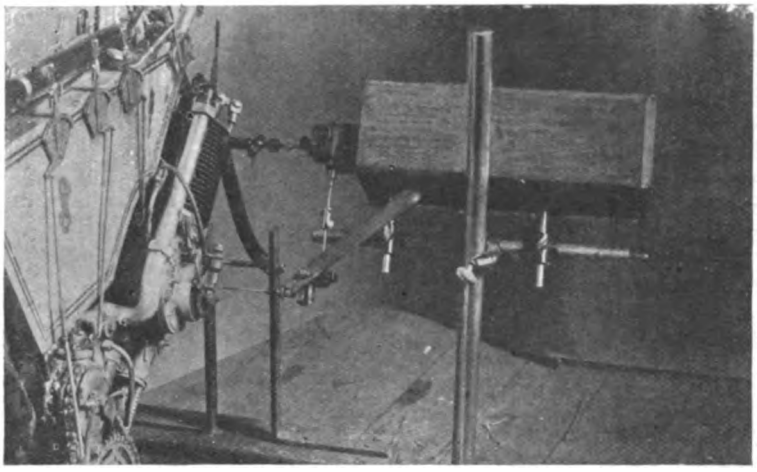

FIG. 1.—METHOD OF CONNECTING THE MANOGRAPH.

INSTRUCTION in the practical use of the indicator is a most essential exercise in the education of every engineer. Trials of experimental engines form part of the regular routine of the instruction in all our technical colleges, and these trials are generally so arranged that each student has an opportunity of taking and working out indicator diagrams for himself. But there is more to learn about the use of the indicator than can be imparted by this method. It is not sufficient to take a few diagrams under normal conditions, with everything in perfect adjustment. To make the best use of the instrument, the student requires to know a good deal of its defects and limitations, to be able to distinguish between an error of the instrument and a defect of the engine under test, and to know how to interpret the indications of the diagram when the conditions are faulty, and when the object is to discover the source of trouble. Time could not well be spared to put each student individually through a course of this kind in the laboratory, even if the experimental engine were so designed as to lend itself readily to all kinds of maladjustments. It is necessary to fall back on lectures and demonstrations. A great deal may be done with the aid of lantern slides and diagrams carefully selected to illustrate defects of various types, but more may be accomplished in the way of interesting the student and rivetting his attention by the actual demonstration of these uses of the indicator with a small engine specially arranged to facilitate rapid readjustment. For demonstration purposes, it is an immense advantage to be able to project the indicator diagram itself on the screen while the engine is working, in such a manner as to be visible to all members of a large class. This greatly economises time, and adds to the clearness and interest of the exposition.

The manograph which I described in an article in the April number of this magazine is eminently suited for this purpose, and may be employed in conjunction with a variety of small high-speed motors such as may now be purchased for the comparatively small outlay of £10 to £20 each. These are readily manipulated, and afford material for a large number of entertaining and instructive experiments with comparatively little trouble or

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expense, as compared with the larger experimental engines usually employed for power tests.

By way of illustration, I propose in the present article to give a series of indicator diagrams, taken with the small petrol motor previously described, with the object of investigating the various conditions affecting the running of this type of engine and the sources of error to which the high-speed indicator is liable.

The method adopted for connecting the indicator to the engine must depend to some

FIG. 2.—NORMAL DIAGRAM.

No Load. Revolutions 2,060. Spark retarded. 10 kg. disc. Short tube connection. Pressure retardation inappreciable.

extent on the type of engine employed. In the majority of cases the arrangement illustrated in Fig. 1 will be found convenient and sufficiently accurate for the purpose. The chamber containing the steel disc for indicating the pressure is connected to the indicator cock, or other suitable opening in the cylinder, by means of a short steel tube about five millimeters in diameter. If no indicator cock is already fitted, the tube must be provided with a tap for disconnecting the indicator, and with a small hole closed by a screw for admitting the atmospheric pressure when required. The piston motion is reproduced as follows. A short steel rod, screwed into the main shaft, transmits the rotation through a pair of bevel wheels to a second rod at right angles to the first, which turns a small crank and connecting rod so as to tilt the mirror from side to side in time with the motion of the piston. To permit of adjustment for different sizes of engine, and to allow the position of the spot of light reflected from the mirror to be set correctly relative to the position of the piston, the second rod is in two parts sliding in a sleeve, with set screws which admit some alteration of length as well as adjustment in phase. The first rod is also provided with a sliding sleeve and a key-way to facilitate disengagement of the indicator when desired. In many respects this method of attachment is not so convenient as that originally adopted by MM. Hospitalier and Carpentier, who employed a long flexible copper tube for transmitting the pressure, and a long flexible connector for the piston motion; but it secures far more accurate results, which is much more important for practical purposes than mere convenience in fitting. As some of my correspondents have failed to appreciate the importance of this point, and appear to think that I have exaggerated the defects in question, or to attribute them to some oversight in the adjustment or fitting of the apparatus, I will first illustrate some of the possible defects of the high-speed indicator, before considering the application of the instrument to investigate and detect defects of the engine.

SOURCES OF ERROR IN THE INDICATOR.

The diagram shown in Fig. 2 was taken with the short tube connection and bevel gear above described at a speed of 2,060 revolutions per minute, the position of the spot of light being accurately set with reference to the piston, so that it should be at the end of its stroke at the same moment as the piston. The adjustment was made by observing the positions of the spot of light and the piston while the engine was turned slowly by hand. The spark was fully retarded, and there was no load on the engine. Under these conditions the expansion line, at the start, should coincide with the compression line. The coincidence shows that there is practically no retardation in the propagation of the pressure to the indicator disc through the short tube connection, even at the high speed of 2,000 revolutions per minute.

FIG. 3.—DISTORTED DIAGRAM.

Taken with long copper tube connection, the conditions being otherwise the same as in Fig. 2.

The diagram shown in Fig. 3 was taken under precisely similar conditions, but with the short tube replaced by the long fine copper tube supplied with the instrument. In this case the attainment of the maximum compression pressure in the indicator is retarded until the piston has travelled some distance along the expansion stroke, which causes the diagram to open out into an oval form. The pressure at any point in the diagram is not the correct pressure existing

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in the cylinder at the time, but is a sort of rough average of the pressures existing during the preceding half stroke. Speaking generally, this has the effect of smoothing out the characteristic inequalities of the curve; but in one respect the opposite effect may be noticed. The rise of pressure due to the explosion is rendered more abrupt than it is in reality, owing to an effect of the inertia of the long column of gas in the tube, which produces an increase of the steepness of the explosion wave in some respects analogous to the bore-wave in a narrow tidal estuary.

In order to correct this distortion, according to the instructions supplied with the instrument, the position of the spot of light was retarded relatively to the piston until the beginning of the expansion line coincided with the compression line at a speed of 2,000 revolutions per minute. This adjustment can only be made when the spark is fully retarded, and holds only for the particular speed at which it is made. By the time the diagram shown in Fig. 4 was taken, the speed had increased slightly to 2,100 revolutions, and the lines no longer coincided accurately. But, even with the compensation correctly made, the diagram is still incorrect and misleading. The maximum compression pressure indicated is about 25 per cent. below the true pressure: the rise of pressure during the explosion is too abrupt; and there is a good deal of residual distortion, due to the fact that the retardation is not a simple time-lag. Thus, whereas in Fig. 2 the pressure falls slightly below the atmospheric at the beginning of the exhaust stroke, the indicated pressure in Fig. 4, even after the compensation has been applied, is still far above the atmospheric at the same point, owing to

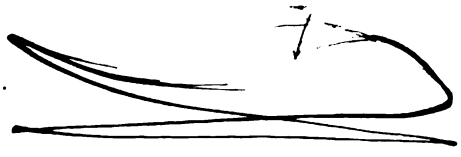

FIG. 4.
The same diagram, with light spot retarded relatively to piston by Carpentier's method, to compensate approximately for pressure retardation.
Showing residual distortion and diminution of indicated compression pressure from 52 to 36 lbs.

the time which the gas in the indicator takes to exhaust through the long fine tube. On these and similar essential points the indications of the compensated diagram are entirely misleading

FIG. 5.—NORMAL DIAGRAM.
Spark retarded. Revolutions, 1,500.
Compression, 34 lbs.

A similar effect of pressure retardation, though with some characteristic differences, may be obtained with the short tube connection by partly closing the tap, so as to throttle the pressure excessively. Fig. 5 shows a correct diagram taken at a speed of 1,500 revolutions, with low compression pressure of 34 lbs. Fig. 6 shows the same diagram dis-

FIG. 6.
The same as Fig. 5, but with the indicator tap partly closed, to throttle and retard the pressure in the indicator.

torted by nearly closing the indicator tap. Fig. 7 shows the effect of retarding the position of the spot of light relatively to the piston till the expansion and compression lines coincide. All the pressures are reduced by the throttling as compared with Fig. 5, and

FIG. 7.
The same as Fig. 6, but with the light spot retarded relatively to the piston until the expansion and compression lines coincide.
Compression pressure diminished by throttling from 34 lbs. to 20 lbs.

all the characteristic points of the diagram are smoothed out. There is here no trace of the "bore-wave" effect observed with the long copper tube, as we have to do merely with

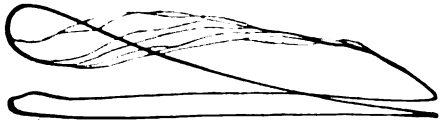

FIG. 8.
The same as Fig. 7, but with the tap opened, showing the effect of the retardation of the light spot relatively to the piston when the pressure in the indicator is not throttled.

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simple throttling. If the speed is varied under these conditions, the form of the diagram changes. An increase of speed gives an oval form similar to Fig. 6, but less pronounced. A decrease of speed introduces a loop at the compression end, as the retardation of the piston phase is greater than that of the pressure. Fig. 8 shows the effect of opening the tap without altering the adjustment. Here the pressures are not retarded or reduced, and the loop form is due to the retardation of the spot of light relatively to the piston, introduced in the adjustment made in Fig. 7. The whole series may be very easily and quickly shown to a large class of students, and is an instructive illustration of the effects of throttling a high-speed indicator.

In order to project the diagrams successfully on a screen, it is necessary to insert in the camera a concave lens close to the mirror, of a suitable focal length to permit the spot of light to be focussed on a screen at a distance of 15 to 20 feet. The small aperture admitting the light should be replaced by one slightly larger than would be used for taking photographs, and an arc light must be employed as the source to obtain sufficient light. It is also, as a rule, convenient to employ a mirror inclined at an angle of 45° to the aperture of the box, if the engine is fixed in an inclined position as in Fig. 1., in order that the atmospheric line may be horizontal on the screen. Otherwise the position of the engine may be adjusted to produce the same effect without the mirror. For taking photographs, or for viewing the diagrams on the ground glass of the camera, a less powerful source of light suffices. The makers supply a small acetylene burner, which will give sufficiently dense photographs if the spot of light is allowed to traverse the diagram some fifty times, provided that the engine is running so steadily that the explosion lines coincide. This is seldom or never the case at high speeds, and most of the characteristic details of the diagram are lost in the resulting blur. In the laboratory, the arc light, with an extremely fine aperture, is the best source to use. When an arc light is not available, I have found that a four-volt testing lamp answers much better than the acetylene flame. The exposure is made by connecting the lamp momentarily to an eight-volt battery, which gives an excessively bright light, sufficient to make each separate line visible in the photograph. The exact position of the igniting spark may be simultaneously recorded on the plate by the method which I have previously described.

When the engine is running under load with the spark advanced, the explosion pressure reaches a maximum shortly after the top of the piston stroke, and it is necessary to employ a thicker steel disc to record the pressure. The diagram shown in Fig. 9 may be taken as a normal full load diagram for

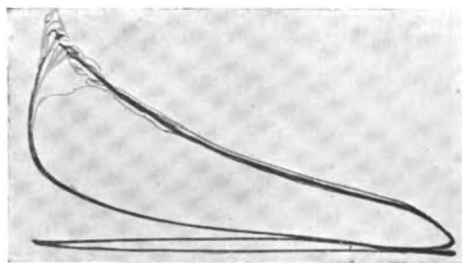

FIG. 9.—FULL LOAD DIAGRAM.

Short tube connection. 20 kg. disc. Revolutions, 2,030. Max. Pressure, 230 lbs. Mean Pressure, 78 lbs. I.H.P., 2·37. B.H.P. (on back wheel), 1·18.

this particular engine. The maximum indicated pressure is 230 lbs. per square inch above atmospheric, which is much smaller than that obtained in large engines for several reasons. The compression ratio, or the ratio of the maximum to the minimum volume of the charge, is only 4 to 1. The mixture is comparatively weak on account of the large proportion of burnt gases remaining in the cylinder, and also because at this comparatively high speed, with a small carburettor and a stiff inlet spring, the pressure at the end of the suction stroke is considerably below the atmospheric. For the purpose for which the engine is designed a higher compression ratio would be of little advantage. The maximum of fuel economy is here of less importance than lightness and smoothness of running. The low compression makes it possible to use a very small and light flywheel, less than 7 lbs. in weight, and only 6·5 inches in diameter. The explosion temperatures are also lower, less heat is wasted, and the engine runs more efficiently because it is kept cooler. It will be observed that the mean pressure realised, namely, 78 lbs., is very fair considering the small size and high speed of the engine, and that the proportion of indicated horse-power to weight, namely, 1 h.p. for less than 9 lbs. weight, is also very high, considering that every detail of the engine is of ample strength, as proved by its excellent wearing qualities under exceptionally severe work.

Fig. 10 shows a full load diagram taken under the same conditions with the *long copper tube* connection, the pressure retarda-

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tion being compensated in the manner previously described, by running the engine at the same speed with the spark fully retarded at no load. The distortion of the diagram is here less obvious than in the preceding instances, but the indicated pressures are far below their true values, and the practised eye would at once detect the residual distortion of the suction and explosion lines.

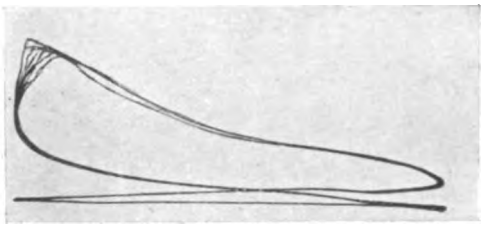

FIG. 10.

The same diagram with Carpentier tube connection, pressure retardation compensated.
Max. pressure, 160 lbs. Mean pressure, 61 lbs.
I.H.P., 1·84. B.H.P., 1·10.

These diagrams illustrate another source of error which it is important to take into account in fitting an indicator to a very small engine. The volume of the indicator and its connecting tube forms part of the compression space, and diminishes the compression ratio, and thus, indirectly, the power of the engine. The volume of the long copper connecting tube was 7 cubic centimeters, and that of the tap and the indicator chamber nearly 3 c.c., making a total added volume of 10 c.c.; the volume of the compression space of the engine itself being only 60 c.c. The added volume is nearly 17%, and the compression pressure is accordingly reduced in a corresponding proportion. By substituting a short tube with a volume of only 1 c.c., the total added volume was reduced to 4 c.c., which is a considerable improvement; but I hope by re-modelling the rest of the apparatus to reduce the correction still further. Provided that the added volume is small, an approximate correction may fairly be made for its effects by assuming that the compression is adiabatic and follows the usual law. This is not strictly accurate, because the mixture is receiving heat from the walls of the hot cylinder during the compression, and I have found that the temperature of the cylinder makes a very marked difference on the compression curve; but it is probable that under similar conditions the compression pressure would be altered in the same ratio, by varying the clearance volume, as if the compression were adiabatic. Making this assumption, the compression pressures in the three cases (1) with the long tube (2) with the short tube, and (3) without the indicator, should be in the proportion of the numbers 6·6, 7·2 and 7·7 respectively, supposing that the suction pressures were the same. The effect in changing the mean pressure is more uncertain and difficult to calculate, but would be about half as great, say in the ratio of 6·9 to 7·2 to 7·45. A mean pressure of 78 lbs. with the short tube should correspond to about 75 lbs. with the long tube (if there were no throttling) and to 80·7 lbs. without the indicator. The indicated horse-power would show a corresponding increase from 2·27 with the long tube, to 2·37 with the short tube, and 2·45 if the indicator were disconnected. This would account for most of the observed increase in B.H.P. with the short tube. An increase of brake horse-power on the back wheel of the bicycle from 1·18 to 1·29 was actually observed when the indicator was disconnected; but part of this increase was due to the disengagement of the bevel gear, etc., which absorbs an appreciable amount of power at these high speeds.

Although the disc and mirror mechanism is incomparably superior, for high-speed work, to the usual piston and pencil arrangement, it is unnecessary to say that its speed is limited by similar considerations with regard to the inertia of the moving parts.

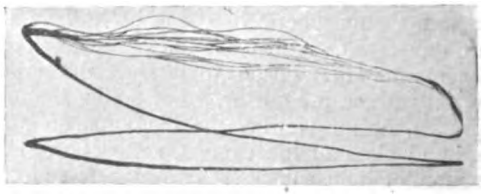

FIG. 11A.
Revolutions, 2,430. Inlet throttled. No load.
10 kg. disc.

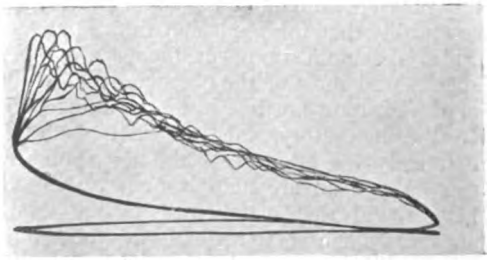

FIG. 11B.
Revolutions, 2,170. Heavy load. 20 kg. disc.
Pressure vibrations due to explosive resonance in indicator tube.

This is not merely a question of revolutions per minute, but also of the rate of rise of the explosion pressure. When running at no load with a weak mixture and small explosion

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pressure, as illustrated by Fig. 11 A, there is little or no trouble from vibrations even at so high a speed as 3,000 revolutions, and with a weak disc. But when running under load with a stronger mixture and a rapid rise of pressure, vibrations begin to appear at much lower speeds. Such vibrations are shown in Fig. 11B, extending throughout the whole of the explosion stroke.

These vibrations would evidently make it difficult to measure the diagram accurately; at this speed they do not appear to be due to inertia of the mirror, because they are so prolonged throughout the stroke, and also because they may be to a great extent suppressed by the simple expedient of inserting a fine disc of wire gauze across the tube con-

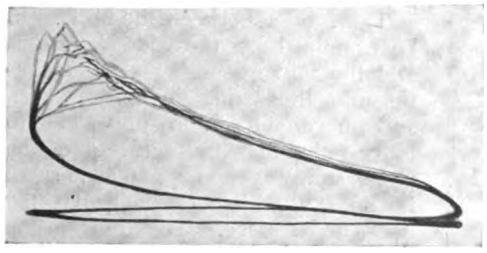

FIG. 12.
Similar conditions, but vibrations damped with gauze in tube. Revs. 2340.

necting the indicator to the cylinder. This is shown in Fig. 12, which was taken under similar conditions at a higher speed, but with the wire gauze inserted in the tube. The vibrations begin as before at the commencement of the explosion stroke, but they are rapidly damped out, so that the greater part of the expansion line is smooth and clear. As the gauze in the tube could have no appreciable effect in damping mechanical vibrations of the mirror, the vibrations must be real pressure vibrations due to explosive resonance in the tube which are faithfully recorded by the mirror. The gauze cannot prevent the mixture exploding in the tube when highly compressed, but it effectually damps out the resulting oscillations of pressure.

At higher speeds with a stronger mixture and more spark advance, as in Fig. 13, these vibrations, though still rapidly damped by the gauze, increase in violence, till at length, as in Fig. 14, with a rich mixture, weak inlet spring, and maximum spark advance, at a speed of 2,600 revolutions the mirror is knocked off its pivot temporarily at each explosion, the diagram becomes an inextricable

FIG. 13.
Revolutions, 2,500. Heavy load. Stronger mixture. More spark advance.
Vibrations increasing in violence.

tangle of lines, and we reach the practical limit of the apparatus in its present form.

It is evident that legible diagrams might still be obtained at higher speeds with the same mechanism by using a stiffer disc in the indicator, which would diminish the amplitude of the vibrations, but I hope to obtain still better results over a wider range of pressure

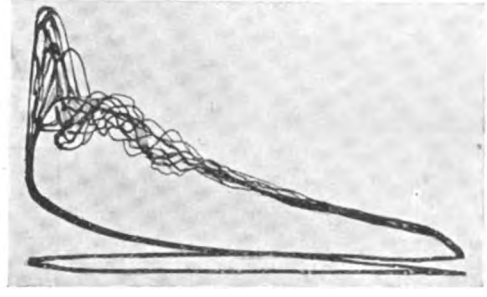

FIG. 14.
Revolutions, 2,600. Rich mixture. Maximum spark advance. Mirror knocked off its pivot at each explosion.

by re-modelling the apparatus in the direction already indicated. It would be easy to make the mirror much lighter and smaller, and to diminish the intensity of the vibrations by restricting the volume of the indicator chamber and its connecting tube. This would improve the accuracy of the diagrams in other respects, especially when used with small engines.

(To be continued.)

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THE FIBROUS CONSTITUENTS OF PAPER.

No. II. Cotton—(*continued*).

By CLAYTON BEADLE.

Illustrated with Photo-micrographs by John Christie, F.R.M.S.

THE chief use, in point of quantity, to which cotton rags are put, is for the manufacture of high-class writing papers. The author considers that the interests of papermakers may best be served by giving a careful account of the physical constants and micro-structure of a high-class writing paper containing cotton. For the purpose of this investigation a number of transverse sections have been cut at right angles to the surface of the paper, both in the "machine" and "cross" directions. These are shown under different magnifications and aspects in the photo-micrographs (Figs. 11 to 16).

It is possible, by the aid of Figs.* 1, 2, and 3, which show the characteristics of the cotton fibre, to distinguish various cotton fibres in the paper sections. Studied in this way, the sections may prove very instructive, more so than any detailed description would be; a few words therefore will suffice.

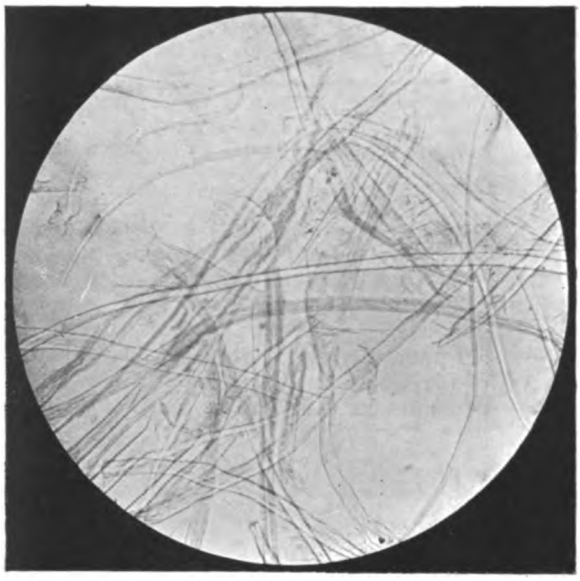

Fig. 9.—Cotton Paper Pulp.
(*Magnified 112 diameters.*)

A high-class writing paper, which appears smooth and perfectly uniform to the eye, creates a very different impression when examined under high powers of the microscope. The sections remind one rather of the cut edge of a truss of hay in which the grass has been thrown down indiscriminately, but with a disposition to point more particularly in one direction.

The spaces between the fibres can be examined by the aid of sections and the microscope. Fig. 16 is particularly interesting in this respect, and on careful scrutiny one is able to look right into the recesses of the paper, in a way perhaps that a small fly might do when crawling over the edges and surface. The fibres, at the time that they are felted together, are in a soft, pliant condition. They become bent, warped, twisted, and assume all sorts of zig-zag shapes. They are frequently "kinked" in their sudden contortions, in a similar manner

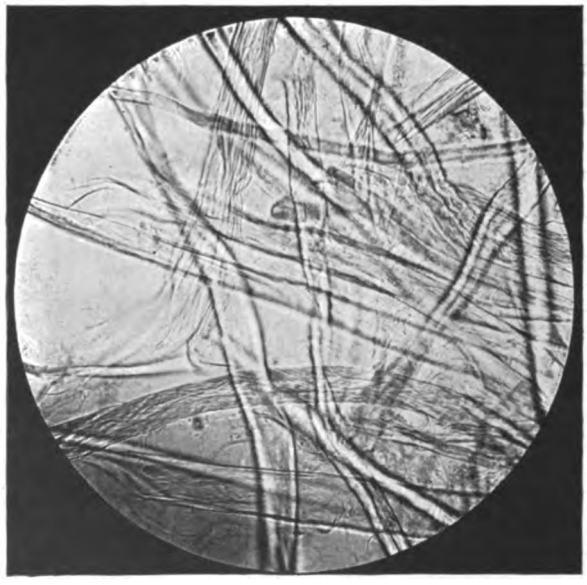

Fig. 10.—Cotton Paper Pulp Bleached and Beaten.
(*Magnified 246 diameters.*)

* Technics, No. 6, Vol. I, pp. 567–569.

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FIG. 11.—TRANSVERSE SECTION OF WRITING PAPER, CUT AT RIGHT ANGLES TO SURFACE, AND IN "MACHINE" DIRECTION.
(*Magnified* 150 *diameters.*)

to that of a rubber hose-pipe when bent at a sharp angle. The fibres, having once assumed these grotesque attitudes, dry down and become rigid, whilst closely interlaced. When a paper is torn asunder, the fibres themselves are not broken, but merely compelled to relinquish their hold on one another. The extent to which they resist is a measure of the strength of the paper. To fully appreciate these points, and give them numerical expression, details of the physical constants of the paper as used for cutting sections are given (pp. 64–65).

FIG. 12.—TRANSVERSE SECTION OF WRITING PAPER, CUT IN "CROSS" DIRECTION.
(*Magnified* 150 *diameters.*)

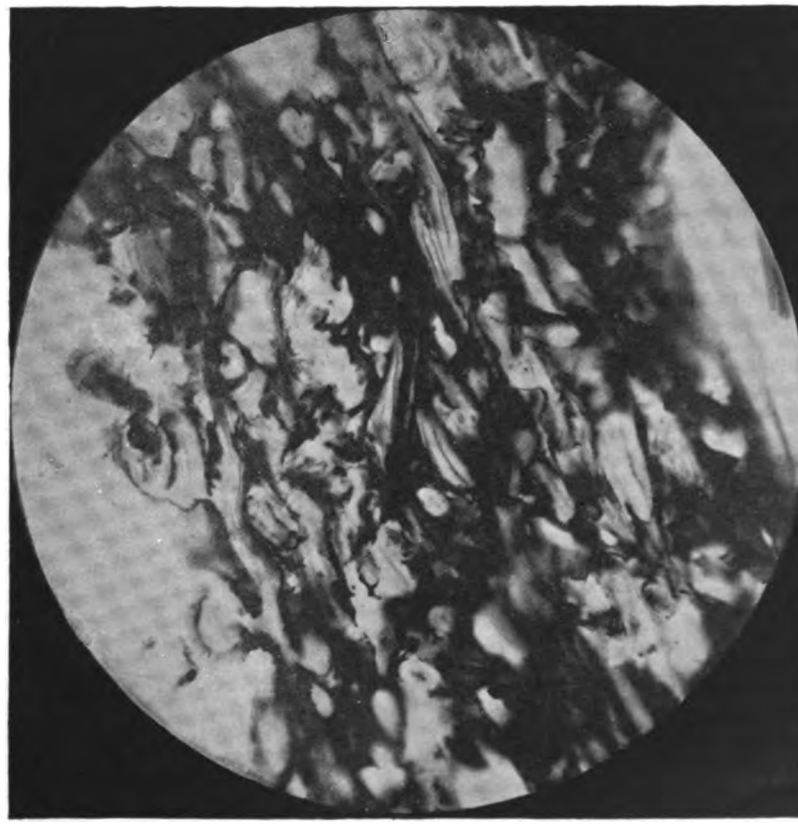

FIG. 13.—TRANSVERSE SECTION IN "MACHINE" DIRECTION, SHOWING BOTH SURFACES.
(*Magnified* 320 *diameters.*)

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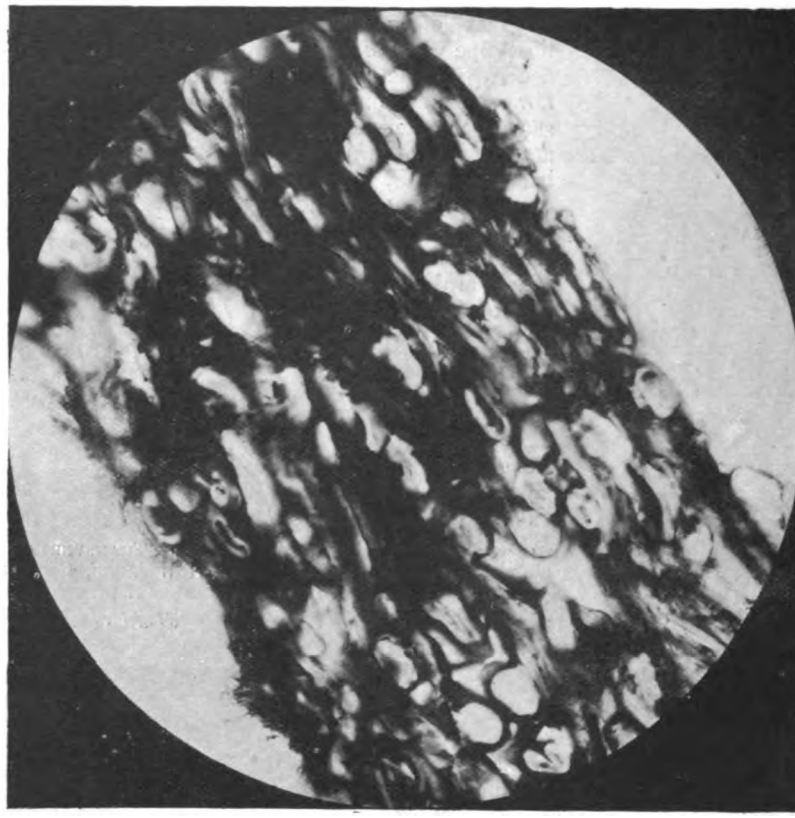

FIG. 14.—TRANSVERSE SECTION IN "CROSS" DIRECTION, SHOWING BOTH SURFACES.
(*Magnified 320 diameters.*)

Mean diameter of cotton fibre as ordinarily measured (*i.e.* maximum way of section) may be taken at ·024 mm. to ·026 mm. The approximation of measurements in the summary (p. 65) is therefore sufficiently close to that of an average figure for the purpose of our calculations.

On the basis that the mean sectional area of the cotton fibre is ·00026 □ mm., and that the mean breaking strain of the cotton fibre is 8·179 grams, the specific breaking strain of cellulose contained in the cell wall of the cotton fibre may be stated at 31,458 grams per □ mm. of sectional area, or 44,748 lbs. per □ inch. The cotton fibre, therefore, has about one-half the tensile strength of steel, is about 50 per cent. stronger than brass, and about three times as strong as cast iron.

From a consideration of the figures given on p. 65, it is evident that the strength of a machine-made paper, as ordinarily expressed, tends to increase as the fibres are compacted together

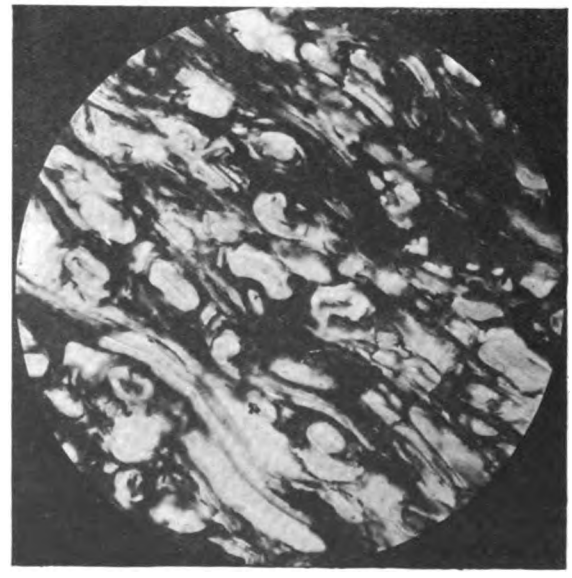

FIG. 15.—TRANSVERSE SECTION OF PAPER, FOCUSSED TO SHOW TRANSVERSE SECTION AND CENTRAL CANALS OF COTTON FIBRES; THE INTERSTICES APPEARING DARK.
(*Magnified 320 diameters.*)

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by the operations of glazing and calendering. If the strength is expressed, as with all ordinary materials, in grams per □ mm. of sectional area, the more compacted paper gives a much higher result.

If we eliminate the factor of air space by assuming the thickness of the paper to be so reduced as to contain no interstices whatever, a figure is arrived at which may be described as the specific resistance of the fibre substance, as given at end of table (p. 65). It will here be noticed that the compression of the paper due to calendering has resulted in a steady increase in strength. By comparing the figures of the specific strength of the cotton fibre with that of the breaking strain in grams per □ mm. of sectional area of the paper, one is led to conclude that high-class writing paper, including air space, has about one-

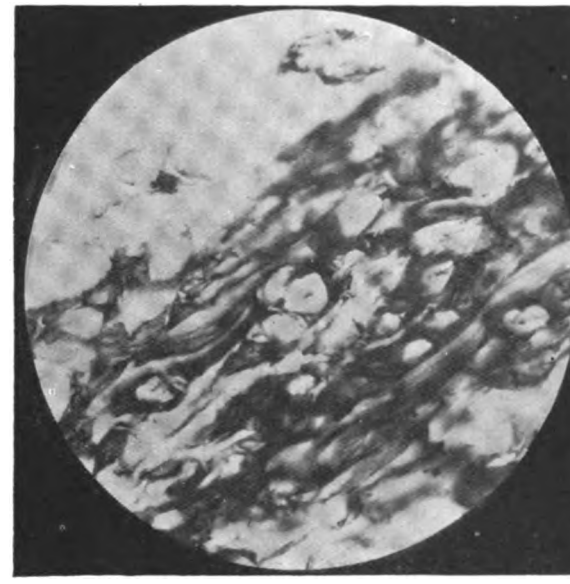

FIG. 16.—TRANSVERSE SECTION FOCUSSED TO SHOW GENERAL APPEARANCE OF INTERSTICES OR AIR SPACES BETWEEN FIBRES. (*Magnified* 320 *diameters.*)

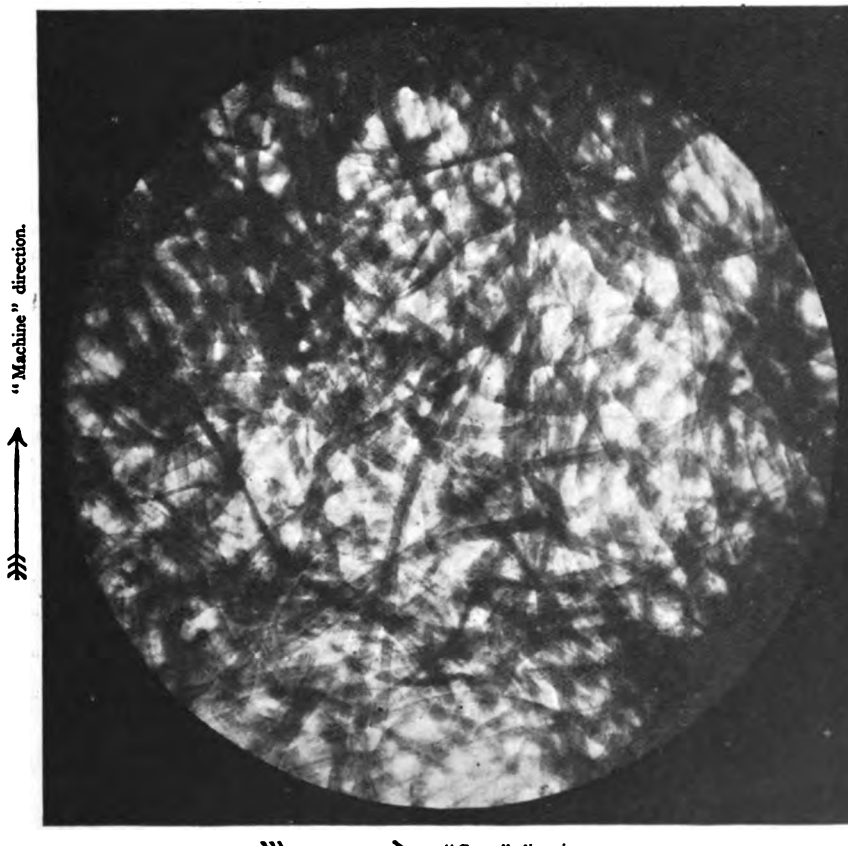

FIG. 17.—SHOWING THE "LIE" OF FIBRES IN THE PAPER USED FOR TRANSVERSE SECTIONS IN FIGS. 11–16. (*Magnified* 90 *diameters.*)

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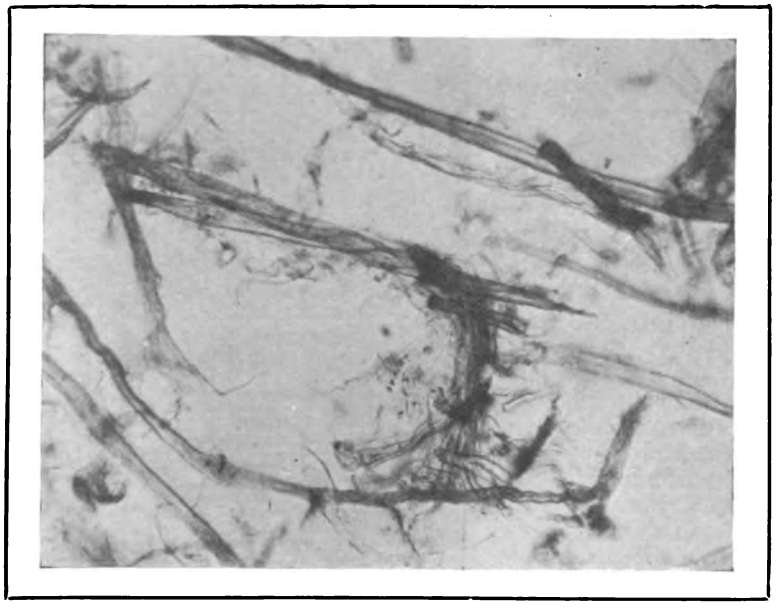

FIG. 18.—SHOWING FIBROUS ELEMENT (COTTON AND LINEN) OF THE CREAM-LAID WRITING PAPER USED FOR SECTIONS (FIGS. 11–16).
(*Magnified* 110 *diameters.*)

seventh the strength of the fibres of which it is composed.

Finally, when comparing the specific strength in terms of the fibre substance of the paper, as previously referred to, with the specific strength of the cellulose constituting the cell walls of the cotton fibres, we find that the paper gives a figure varying between 6,836 and 7,371. The cellulose of the fibre substance gives the figure 31,458 grams per □ mm. We conclude from this that the fibres relinquish their hold of one another when a force is applied equal to about one-quarter that necessary to rupture the fibre substance. One would naturally conclude from this, that a high-class writing paper is not made particularly with a view to the greatest possible strength, but with other qualities in view, and this is the case. With very strong papers, such as hand-made loans and such-like papers made with a preponderance of linen fibre, treated in a way to give them maximum strength, we shall find that these figures bear a different relationship to one another. It is proposed to deal with this on some future occasion.

ANALYSIS OF FIG. 17.

Table showing Inclination of Various Fibres in Fig. 17 to "Cross" Direction (from left to right).

No. of Fibre.	Inclination.	No. of Fibre.	Inclination.	No. of Fibre.	Inclination.	No. of Fibre.	Inclination.
1	85°	12	87	23	80	34	96
2	95°	13	89	24	90	35	105
3	103	14	115	25	90	36	80
4	110	15	147	26	95	37	85
5	95	16	130	27	115	38	90
6	98	17	104	28	60	39	115
7	100	18	50	29	60	40	30
8	85	19	47	30	110	41	60
9	155	20	65	31	50	42	80
10	130	21	65	32	140	43	70
11	65	22	94	33	154	44	60

Mean inclination of fibres to "cross" direction = 90·64°

CREAM-LAID SUPERFINE WRITING PAPER, BEST QUALITY.

Percentage by weight.	Per cent.
Fibres derived from treatment of high quality rags—about one-third linen and two-thirds cotton	91·0%
Mineral Matter, due to natural ash and added alum	1·5%
Gelatine, prepared from hide pieces and applied to web of paper . . .	7·5%

THICKNESS OF PAPER AT DIFFERENT STAGES.

Stages.	m.m.
1. Rough paper after sizing	0·198
2. Paper after passing through single sheet smoothing rolls	0·176

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	m.m.
3. Finished paper, after plate glazing by passing repeatedly between rolls under heavy pressure and in contact with copper plates	0·134

	1	2	3
Total grams per cc. .	0·612	0·679	0·928
Fibre ,, .	0·558	0·619	0·844
Mineral ,, .	0·009	0·010	0·014
Gelatine ,, .	0·045	0·050	0·070
Percentage by volume—			
Fibre . . .	37·2%	41·2%	61·2%
Mineral . .	·4%	·4%	·6%
Gelatine . .	3·6%	4·0%	5·6%
Airspace . .	58·8%	54·4%	32·6%
Mean strength in lbs. on strip 1 in. wide—			
5 tests in "machine" direction . .	32·6	33·0	41·0
5 tests in "cross" direction . .	23·0	23·9	25·4
Mean of both directions	27·8	28·45	33·2
Mean strength in grams of strip 25 mm. wide .	12593	12887	15039
Mean sectional area of strips broken, in □ mm. . .	4·95	4·40	3·33
Mean breaking strain in grams per □ mm. of sectional area . . .	2543	2927	4511
Ratio of strength of "machine" to "cross" direction ("machine" = 100)	100: 70·5	100: 72·4	100: 61·9
Mean breaking strain in grams per □ mm. of sectional area per unit of fibre substance .	6836	7104	7371

MEASUREMENTS OF TRANSVERSE SECTIONS OF COTTON FIBRES FROM PHOTO-MICROGRAPHS OF TRANSVERSE SECTIONS (× 300) TAKEN AT MAXIMUM AND MINIMUM FOR EACH SECTION.

Section.	Maximum. (× 300).	Minimum. (× 300).	Max. × Min. showing relative areas.	Ratio when maximum = 100.
1	7·7 mm.	4·6 mm.	35·42	59·7
2	6·8 mm.	2·0 mm.	13·60	29·5
3	6·3 mm.	1·7 mm.	10·71	26·9
4	9·0 mm.	3·0 mm.	27·00	33·3
5	7·2 mm.	3·3 mm.	23·76	45·9
6	8·0 mm.	3·5 mm.	28·00	43·9
7	7·2 mm.	4·7 mm.	33·84	65·4
8	7·2 mm.	2·4 mm.	17·28	33·3
9	10·4 mm.	1·9 mm.	19·96	10·3
10	9·0 mm.	2·7 mm.	24·30	30·0
Mean	7·88 mm.	2·98 mm.	23·38	37·82

REDUCED TO ACTUAL DIMENSIONS.

Sections.	Sectional Area.	
1 to 10 .	·02627 × ·00993 = ·0002608	□ mm.
11 to 20 .	·02720 × ·00940 = ·0002557	,,
21 to 30 .	·0246 × ·00783 = ·0001946	,,
Mean .	·02602 × ·00905 = ·0002360	,,

SUMMARY OF RATIOS.

1 to 10 . . .	37·82
11 to 20 . . .	34·56
21 to 30 . . .	31·76
Mean of 30 sections (1 to 30)	34·71

MEAN STRENGTH OF COTTON FIBRES CALCULATED FROM O'NEILL'S FIGURES FOR DIFFERENT VARIETIES OF COTTON.

	Grains.	Approximate equivalent in grams.
Maximum (Surat Comptah).	163·7	10·594
Minimum (Tea Islands) .	83·9	5·437
Mean of 10 varieties . .	126·4	8·179

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A NEW PROCESS FOR THE PROTECTION OF IRON AND STEEL FROM CORROSION.

By SHERARD COWPER-COLES.

ZINC has proved the most effective coating for iron and steel, and hot galvanising, with all its attendant disadvantages, is the process most extensively used for applying the zinc coating. Electro-zincing, or cold galvanising, is used for special classes of work, and is extensively used by the Admiralty for giving boiler tubes a thin flashing of zinc for the purpose of detecting flaws and protecting the tubes from corrosion during the time of assembling and erection.

Works have just been completed for a new process, to which the name of "Sherardising" has been given. One point of particular interest about the new process is that iron and steel can be coated with a thin, even deposit of zinc at a temperature many hundreds of degrees below the melting point of zinc.

The first step in the process is to free the iron from scale and oxide by any of the well-known methods, such as dipping in an acid solution or sandblasting. The articles to be protected are then placed in a closed iron receptacle, charged with zinc dust which is heated to a temperature of from 500° to 600° F. for a few hours and allowed to cool; the drum is then opened and the iron articles removed, when they are found to be coated with a fine homogeneous covering of zinc, the thickness depending on the temperature and the length of time. It will be observed that the temperature required to bring about this result is about 200° F. below the melting point of zinc. The low temperature required makes the process cheap as compared with the process of dipping in molten zinc; and has the additional advantage that it does not deteriorate iron or steel of small section to the same extent as hot galvanising. The whole of the zinc dust is consumed; there is no waste of zinc, as in the hot galvanising process. This new process of galvanising is not limited to the coating of iron with zinc; it has been successfully applied to coating iron with copper, aluminium, and antimony. It has also been applied to coating various other metals—for instance, aluminium and copper with zinc. Copper and its alloys subjected to this process are case-hardened on the surface, and can be rendered so hard as to turn the edge of a steel tool.

The zinc powder used in the process is the zinc dust of commerce, and must not be confused with zinc oxide: it is obtained during the process of distilling zinc from its ores. Zinc dust at the present time is used for a variety of purposes, and can be obtained in any desired quantity. The average price of zinc dust, during the year 1903, was £19 19s. per ton, which is slightly below the average price of virgin spelter. The analysis of two samples of zinc dust, such as are employed for Sherardising, gave respectively 85, 85·06, and 81·86 per cent. metallic zinc. Both samples, when examined under the microscope, were seen to contain small bright metallic beads unevenly distributed through the dust; and it is probable that this may account for the different percentages obtained by analysis. One of the peculiar properties of zinc dust is that it cannot be smelted or reduced to the metallic form under ordinary conditions, even when heated to a very high temperature under considerable pressure. This property is very advantageous for the new process of dry galvanising (Sherardising), as it does away with the risk there might otherwise be of melting the finely divided zinc by overheating the furnace. The receptacle in which the zinc dust is placed and heated is preferably air-tight, and the air exhausted so as to prevent the formation of too much zinc oxide; or if this is not feasible, it is found advisable to add about 3 per cent. of carbon in a very fine state of division. If the percentage of oxide is allowed to increase beyond certain limits, it is found that the deposits become dull in appearance, instead of having a bright metallic lustre, although good deposits of zinc can be obtained from zinc dust, varying considerably in composition. To prevent the

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iron receptacle in which the process of Sherardising is carried on from becoming thickly coated with zinc, it is found advantageous to coat the inside of the drum with plumbago or black lead. Articles coated with grease receive as good, if not a better coating of zinc than those which are free from grease. This fact is of considerable importance, as it enables machine work such as bolts, nuts, screws, etc., to be charged direct after machining into the Sherardising drum without any preparation or cleaning. The articles, when they have been heated in the zinc dust for the period necessary to obtain the thickness of zinc required, can be removed whilst the zinc dust is still hot, although the better practice is to allow the zinc dust to cool to a temperature at which the articles can be readily handled, as the deposit of zinc is whiter, and less oxide of zinc is formed. This new process of dry galvanising offers many facilities and great economy to those manufacturers who have not sufficient work to keep a large bath of molten zinc continuously at work. Articles can be Sherardised at a few hours' notice, starting all cold; as the drums can readily be heated by gas or coke furnaces, the whole operation occupying only a few hours. When the plant is not at work there is no waste, as in the case of hot galvanising, where the zinc has to be kept in a molten condition day and night.

A useful type of furnace for small work consists of a closed iron chamber (Fig. 1) in the form of a cylinder or polygon, arranged to be rotated or oscillated about an axis. The chamber is provided with an iron door either at one end or at the side, depending upon the class of articles to be treated; a side door is found to be the most suitable for small articles, such as bolts, nuts, small castings, etc., and the end doors for tubes, oblong or cylindrical articles. In the latter case the cylinder is oscillated on its axis; in the former case it is rotated and provided with baffle plates, to ensure the articles under treatment being turned over, and thus becoming uniformly coated by bringing all parts into intimate contact with the zinc dust. Fig. 1 shows such a furnace suitable for Sherardising one or two cwts. of small articles at a time; one of the trunnions is made hollow, so that a pyrometer can be inserted. Below the furnace is arranged a number of Bunsen gas burners for heating the drum, and the whole is enclosed in a cast-iron shell lined with fire-brick. The drum can be rotated either intermittently by hand, or continuously by means of a suitable gearing. The plant required must of necessity be modified to suit the different classes of work;

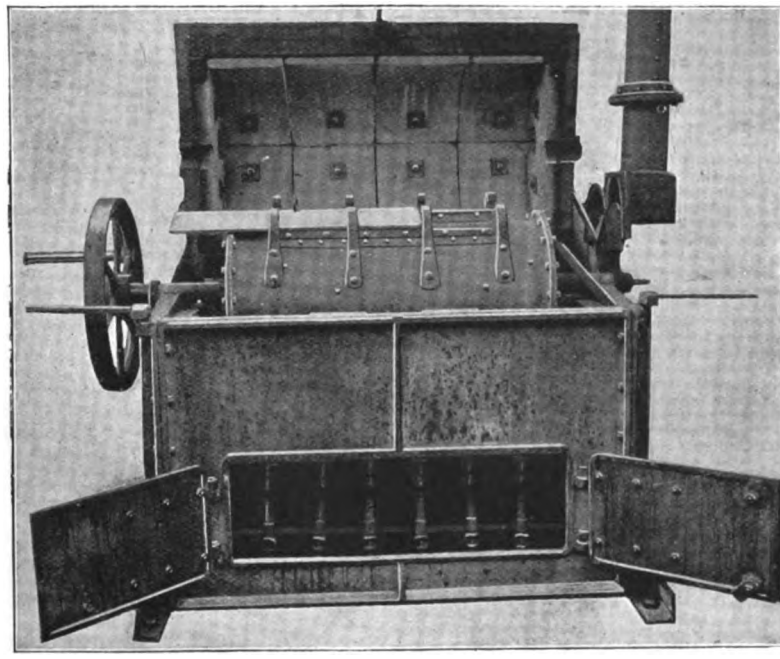

FIG. 1.—GAS FURNACE FOR SHERARDISING SMALL ARTICLES.

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for instance, if it is required to Sherardise an expanding gate or girder, an iron box would be used, which would be kept stationary during the process of Sherardising, the gate being open to its full extent during the operation. Tubes require a different construction of drum from that used for bolts and nuts; wire and sheets also require modified arrangements to enable the work to be handled expeditiously.

The charging of the drum is effected by running the truck on which it is placed on to a table, one end of which is lowered by means of gearing, so as to raise the open end of the drum, into which the zinc dust is charged from an upper floor by means of a shoot F, as shown in Fig. 2. G is a drum being discharged over an iron grating which allows the zinc dust to fall into a chamber below, from which it is raised by means of a chain elevator to the floor above. When a drum is charged with zinc dust and the articles to be Sherardised, it is brought into a horizontal position, the air is exhausted, and the truck is run along the lines until it arrives in front of the furnaces. It is then lifted on to a furnace truck, the object being to effect a saving in the first cost of the trucks and to avoid waste of heat. The drum is then pushed into the furnace, the door lowered, and the furnace heated up to the desired temperature. The heat is regulated in accordance with the readings of a thermometer, which is placed in a vertical iron tube inside the furnace. When the drum has been in the furnace a sufficient time to give the desired result, the door is raised and the drum and carriage withdrawn, the drum lifted on to another carriage and run into an open yard, where it is allowed to cool down to a temperature low enough to admit of easy handling.

FIG. 2.—DRUMS DURING CHARGING AND DISCHARGING.

The zinc surfaces obtained by hot and cold galvanising, and Sherardising, are essentially different; they can readily be distinguished by anybody conversant with the three processes. In the case of hot galvanising, the surface is spangled, or if not spangled, it has the appearance of cast metal. In the case of cold galvanising, the surface is free from spangles and has a matt or frosted surface, uniform if the work has been well executed. Sherardising is again distinctive from the two former processes; the general appearance resembles more that of cold galvanising than hot galvanising, but is more lustrous and metallic, and is uniformly distributed over the whole surface, which is not the case with the hot and cold galvanising processes. The Sherardising process, although similar to cold galvanising in some respects, is also similar to hot galvanising in other respects, inasmuch as the zinc alloys with the iron and forms a protective zinc iron alloy intermediate between the zinc coating and the underlying metal. Fig. 3 shows a photo-micrograph of hot galvanising: the line in the centre shows the line of demarcation between the crystal or spangles. Fig. 4 shows zinc electro-deposited by the regenerative process from a solution of zinc sulphate, kept in the

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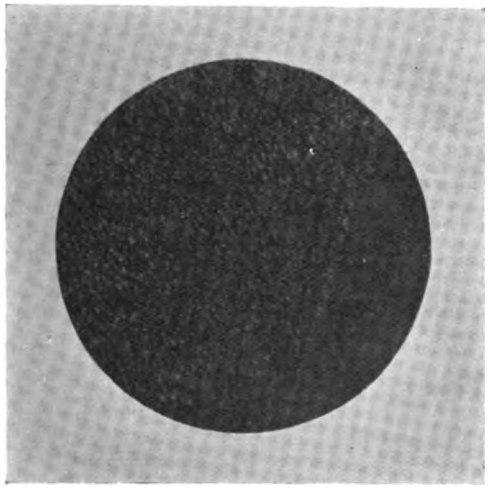

FIG. 3.—HOT GALVANISING.

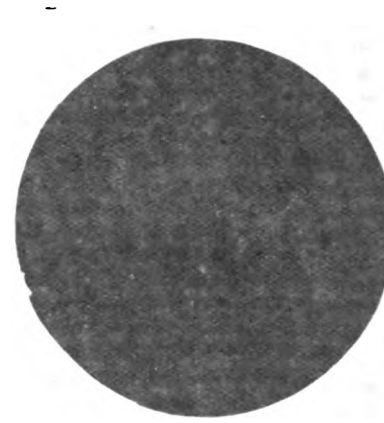

FIG. 4.—COLD GALVANISING.

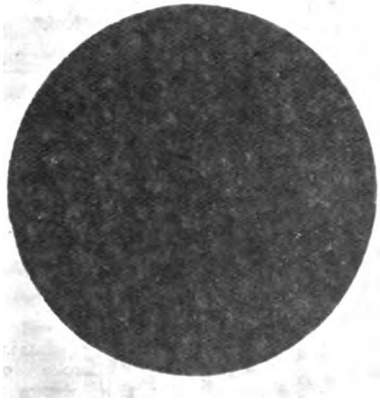

FIG. 5.—SHERARDISED IRON SURFACE.

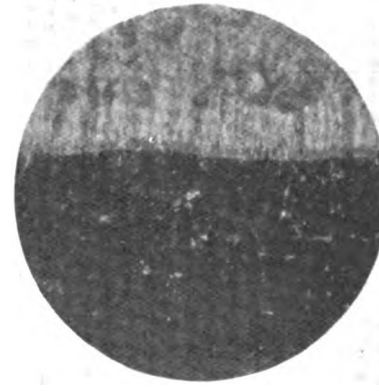

FIG. 6.—TRANSVERSE SECTION OF SHERARDISED IRON.

best working condition by passing the electrolyte through a filter bed of zinc dust and coke; the current density being about 20 amperes per square foot of cathode surface. Fig. 5 shows an iron surface coated with zinc by the Sherardising process.

In practice, Sherardised iron and steel is found to withstand the ordinary corrosive agents galvanised iron is exposed to, to a remarkable degree; even after the apparent removal of all the zinc by filing or abrasion, the iron is still non-corrosive. This valuable property is doubtless due to the protective action of the zinc-iron alloy formed on the boundary line between the iron and zinc, and which is clearly shown on the photo-micrographs Nos. 6 and 7.

As Sherardising is effected at a very much lower temperature than hot galvanising, the temper of steel wire is not reduced, as it is in the latter process. A number of steel and iron bolts, Sherardised at varying temperatures, when tested were found to be equal in tensile strength to bolts which had not been Sherardised. The following table (p. 70) gives the results of tests for tensile strength upon four untreated and four treated Sherardised specimens of steel rod.

The dry process has the following advantages over hot galvanising:—

(*a*) There is no waste of zinc.

(*b*) Less zinc is required to give a good protective coating, because the zinc is evenly distributed.

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(*c*) The temperature required is lower, consequently the amount of fuel consumed is less.

(*d*) The labour is less, as the articles do not require to be cleaned as carefully as in hot galvanising.

(*e*) The cost of working is less than hot galvanising, the plant is very much cheaper.

(*f*) No flux is required, no dross or skimmings formed.

(*g*) No danger of explosion or breaking of castings and distorting of thin iron work.

Sherardised machine work does not require refitting, as the coating is evenly distributed. There is no reduction in tensile strength, as in the case of hot galvanising: the coating is more uniform and even than that obtained in hot or cold galvanising: the work can be placed direct in the Sherardising drum from the pickling vat without drying: the process can be worked intermittently without waste: iron can be coated with zinc to any desired thickness. Another advantage of Sherardising, provided sufficient time is given, is that it has the effect of bringing the surface into a more uniform state of tension.

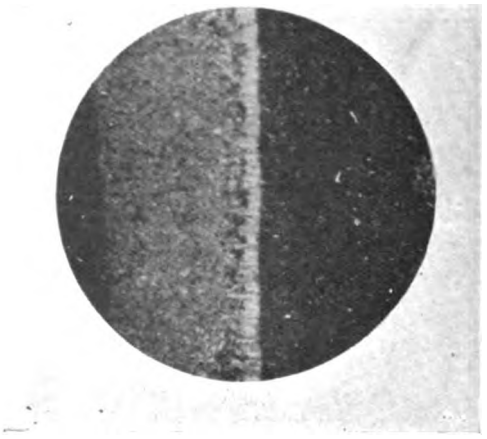

FIG. 7.—TRANSVERSE SECTION OF SHERARDISED IRON.

Dimensions.	Extension.			On Original Area.				Remarks.
	Area Square Inches.	Reduction of Area at Fracture.	On Two Inches.	Elastic Limit (Yields Point).		Maximum Stress.		
				Pounds.	Tons.	Pounds.	Tons	
		Per Cent.	Per Cent.	Per Square Inch.	Per Square Inch.	Per Square Inch.	Per Square Inch.	
Untreated Steel Rod :								
0·276 × 0·277 . .	0·0774	—	1·0	70,358	31·41	121,676	54·32	Irregular Fracture, broke outside datum points in jaws.
0·274 × 0·274 .	0·0750	6·6	3·0	49,280	22·0	150,796	67·32	Broke outside datum points in jaws.
0·278 × 0·278 . .	0·0772	—	3·5	73,987	33·03	149,408	66·70	Irregular Fracture, broke outside datum points in jaws.
0·283 × 0·268 . .	0·0758	3·7	3·0	69,440	31·00	153,932	68·72	Broke outside datum points in jaws.
Sherardised Steel Rod :—								
0·279 × 0·285 . .	0·0795	19·9	7·0	113,545	50·69	156,598	69·91	
0·274 × 0·279 . .	0·0764	6·7	4·0	102,032	45·55	148,064	66·10	Steel Rods Treated.
0·274 × 0·283 . .	0·0775	15·9	6·0	Not observable		154,918	69·16	
0·276 × 0·284 . .	0·0783	4·8	3·5	108,147	48·28	149,632	66·80	Broke outside datum points in jaws.

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CATALYSIS.

PART I.

By T. SLATER PRICE, D.Sc., Ph.D., Head of the Chemical Department, Birmingham Municipal Technical School.

CATALYTIC phenomena are among the first met with in the study of chemistry. Generally they are merely incidentally referred to in the text-books, without reference to the very important part they play in natural and manufacturing processes. Probably the first instance met with is in the preparation of oxygen from potassium chlorate; the addition of manganese dioxide to the chlorate brings about evolution of oxygen at a much lower temperature than is necessary in the absence of this substance. If the reaction mixture is examined after all the potassium chlorate has been decomposed, it will be found that the manganese dioxide remains behind, practically unaltered: the temperature of decomposition was not high enough to decompose it. The manganese dioxide thus appears to help on the reaction, without it itself undergoing change. Such a substance is said to act "catalytically," and to be a "catalyst." Berzelius, in the year 1835, was the first to ascribe the name "catalytic" to reactions which are influenced by the presence of a substance which itself undergoes no change. Berzelius only gave a name to this class of phenomena, without making any attempt to give an explanation. This is important to bear in mind, since it is so often imagined that the "naming" of any phenomenon is tantamount to giving an explanation of the same. The "naming" is only useful because it enables us to group together a number of related phenomena under one heading.

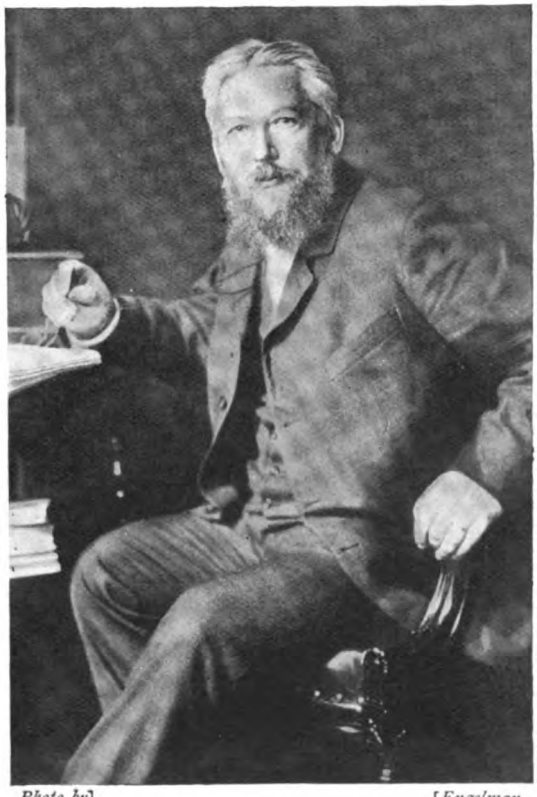

Photo by [*Engelman.*

PROFESSOR OSTWALD.

It is only during the last few years that the study of catalysis has been taken up in a systematic manner, and for this we are chiefly indebted to the work of Professor Ostwald and his students. In an address which Professor Ostwald gave to the "Versammlung Deutscher Naturforscher und Ärtzte" at Hamburg in September, 1901, he gave a very interesting summary of catalytic phenomena, besides bringing forward a number of new ideas on the subject. He divides catalytic reactions into the following four groups.

1. Crystallisation of supersaturated solutions on the addition of a nucleus of the solid salt.
2. Catalysis in homogeneous mixtures.
3. Heterogeneous catalysis.
4. Action of enzymes.

It will be most convenient to follow his method, and discuss each of these groups separately. Group 4 will not be dealt with at present.

I. CRYSTALLISATION OF SUPERSATURATED SOLUTIONS.

One of the chief characteristics of a catalytic reaction is, that a small quantity of a catalyst produces very marked results. This is very well shown in the case of the crystallisation of supersaturated solutions. Thus, if we make a solution of Glauber's salt, which is saturated at

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a high temperature, and cool it down to the ordinary temperature, taking care to keep it out of direct contact with the air of the room, crystallisation does not take place, and a supersaturated solution is obtained. The most recent research has shown that the only way to bring about crystallisation is to drop in a crystal of Glauber's salt. Shaking, scratching, etc., will not start crystallisation if great care is taken to keep away all traces of the solid salt, and if the supersaturation does not exceed a certain limit, or, what is the same thing, the temperature does not fall too low. In the case of Glauber's salt, very great care has to be taken in order to be quite successful, since particles of the salt are always to be found floating about in the air, and consequently exposure of the solution to the air for a very small time will almost certainly bring about crystallisation. Much better results can be obtained by using sodium acetate or sodium thiosulphate. In the latter case a supersaturated solution can be obtained by simply melting the crystals in their water of crystallisation. Professor Ostwald has shown that the quantity of solid salt necessary to bring about crystallisation is far less than a weighable amount, being from 10^{-10} to 10^{-12} gram. The amount necessary is not infinitely small, however, since smaller quantities than the above do not bring about crystallisation. There are a number of ways in which these results can be arrived at. One method is as follows:—weigh out 1 gram of the salt and mix it very intimately with 9 grams of an indifferent substance; 1 gram of this intimate mixture is then mixed with another 9 grams of the indifferent substance, and so on. In this way we get a kind of dilution of the active substance, it being only necessary to take great care that the mixing is very intimate. Then, if a quantity of the mixture is weighed out and the supersaturated solution tested with it, the amount of active substance contained in the mixture weighed out is known, and consequently the amount necessary to bring about crystallisation can be found.

These supersaturation phenomena are of great importance to the analytical chemist, although they do not perhaps play such an important part in manufactures. Thus, in the case of the precipitation of calcium and strontium as sulphates, by the addition of the soluble sulphates to solutions of the chlorides, it very often happens that precipitation does not take place immediately, especially when the solutions are not concentrated. The student is thus very liable to overlook the presence of these metals, if he has not patience to wait for a short time before proceeding with other tests. It is simply a case of supersaturation. This is also the case with the precipitation of potassium as potassium platini-chloride. In this case, however, crystallisation may be brought about by vigorous shaking, or by scratching the sides of the test tube with a glass rod. This is one of the very few cases where crystallisation can be brought about by such mechanical means, and so far no reasonable explanation has been given.

Crystallisation may also be brought about by the addition of a crystal of an isomorphous substance: this gives us an additional test for isomorphous substances. In this connection it is interesting to note that all gases are isomorphous one with another, and consequently any one gas will remove the supersaturation of any other gas. This can be well shown in the case of soda-water; when a bottle of such aerated water is opened there is an immediate liberation of carbon dioxide, effervescence taking place. The effervescence soon dies down, however, and a supersaturated solution of carbon dioxide in soda-water remains. If, now, a piece of lump sugar is thrown into the soda-water, vigorous effervescence immediately commences, because the air contained in the pores of the sugar acts as a nucleus for the formation of bubbles of carbon dioxide. It should be noticed in the case of a supersaturated gas solution, that once the evolution of gas has commenced it does not necessarily continue until all the gas has been evolved. The process will go on only so long as there are nuclei for the gas to form round; these nuclei, however, disappear after a time, since the gas leaves the liquid when the bubble has been formed, and a supersaturated solution may still remain. This can be seen in the case of the soda-water. A second lump of sugar put in after the first has dissolved will again cause effervescence, showing that the supersaturation was not completely done away with by the first lump.

The fact that crystallisation can only be brought about by a crystal of the same or of an isomorphous substance is of very great importance to the organic chemist. One of the most important problems of the present time is the splitting up of compounds, inactive with regard to polarised light, into their active components. It very often happens that the chemist is able to synthesise a compound which should be optically active; the product he obtains is, however, inactive, because just as much of the dextro- as of the laevo-modification will be produced. How is he to split it up? In some cases this can be

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done by making a supersaturated solution of the substance, and then adding a crystal of one of the active modifications, which has been obtained from the natural product or in some other way; the result is a crop of crystals of this active modification and the consequent splitting up of the inactive substance. This process can readily be illustrated with a mixture of the supersaturated solutions of sodium acetate and sodium thiosulphate. If a nucleus of one of these salts is added to a mixed solution of the two, only that salt crystallises out, the other remaining in solution.

II. Catalysis in Homogeneous Mixtures; and III. Catalysis in Heterogeneous Mixtures.

These form the most important divisions of catalytic reactions, both from a theoretical and a practical point of view. It will first be necessary for us to obtain a clear idea of what we mean by catalysis before proceeding with the study of these divisions. The case is altogether different from the one we have just been considering. We saw there that the only condition necessary for the reaction to commence was the addition of a nucleus of the new phase to be formed. Once this nucleus was added the reaction proceeded to an end. That this will not hold in the present case can be seen by the consideration of the influence of iron salts on the rate of oxidation of hydriodic acid by means of hydrogen peroxide. The iron salt is not one of the products of reaction, but nevertheless it brings about an enormous increase in the velocity of the reaction.

The definition given by Professor Ostwald is as follows:—"*A catalytic agent is any substance which affects the velocity of a chemical reaction without itself appearing in the final products.*" This definition includes the idea that a catalyst does not cause a reaction to take place which would not do so in the absence of the catalyst, *i.e.*, a catalyst is incapable of starting a reaction, it can only influence the rate or velocity of the reaction. This may at first sight appear strange, especially when we consider the experiments of Dixon, which have shown that perfectly dry carbon monoxide and oxygen will not combine together when a spark is passed through the mixture, but that a trace of water will cause combination to take place. It appears as if, in this case, the presence of the moisture is the real cause of the reaction. However, thermodynamics teaches us that in such a system, where change can take place with a diminution in the free energy, the change must necessarily occur, but it may be indefinitely slow. This may seem to be an attempt to evade the difficulty, but it is really not so. We have only to consider a common example, such as the burning of coal. We know that when we put it on the fire it soon disappears by combustion. At the ordinary temperature, however, it appears as if it could be kept indefinitely without combustion taking place, although the oxygen of the air is present ready for the combustion. This is the conclusion one would come to if the coal were only observed for a few days; if, however, coal is kept exposed to the air for, say, about six months, it is found that it has decreased in weight and also deteriorated to a very great extent. This is because combustion has really been going on at the ordinary temperature all the time, resulting in the formation of carbon dioxide and water, and consequent decrease in the weight of coal. (This phenomenon is of immense importance where large stocks of coal have to be kept, as, for instance, at the coaling stations of the navy; since the deterioration of the coal means a very great yearly loss of money). Thus in this case we only observe that a reaction has taken place when the observation is extended over a long period of time: if we judge from a short time only, we should say that no reaction takes place at the ordinary temperature, which would obviously be a wrong conclusion. We are, therefore, perfectly justified in extending the argument, and saying that if a reaction can take place it does actually take place, but that the velocity of reaction may be indefinitely slow, unless the conditions are altered, as, for example, by the addition of a catalyst.

It will be noticed that this definition of a catalyst does not attempt to give any explanation of its action, nor does it exclude the case where the presence of an apparently foreign substance retards, instead of accelerating, the reaction. Before dealing with the explanations which have been given of catalytic reactions it will be just as well to describe a number of typical cases, as it will be quite impossible to deal with even a small fraction of the numerous examples of catalysis.

One of the most general cases is the liberation of iodine from an iodide by means of an oxidising agent. This may be effected either by the action of hydrogen peroxide, bromic acid, or potassium persulphate. Suppose we take the last reaction. The equation is

$$K_2S_2O_8 + 2KI = 2K_2SO_4 + I_2.$$

It is found that the addition of small quantities of ferrous sulphate to the reaction mixture

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has a very great accelerating effect. This is shown by the following figures; in each experiment the strength of the potassium persulphate in the reaction mixture was $\frac{1}{80}$ normal, that of the potassium iodide being $\frac{1}{40}$ normal.

$FeSO_4$ concentration.	Time.*	Acceleration.
0	100 mins.	—
$\frac{1}{4000}$ molecular.	18·5 ,,	441
$\frac{1}{8000}$,,	31·5 ,,	217
$\frac{1}{16000}$,,	46·5 ,,	115
$\frac{1}{32000}$,,	64·0 ,,	56
$\frac{1}{64000}$,,	78·5 ,,	27

If these figures are examined, it will be seen that the catalytic effect is proportional to the concentration of the catalyst. Thus, as the concentration of the ferrous sulphate is halved the acceleration is halved. This is not, however, found to be the case in every catalytic reaction.

Further experiments show that it is immaterial whether the iron is added to the reaction mixture in the ferric or the ferrous state. The acceleration produced simply depends on the absolute amount of iron in the mixture. Moreover, it is necessary for the iron salt added to be dissociated, *i.e.*, the ions play the part of catalyst.

Similar results are obtained when copper sulphate is added; the acceleration produced is, however, not so great as with the equivalent amount of an iron salt. In this case, also, the catalytic effect is proportional to the amount of catalyst added.

The most interesting case is, however, when a mixture of copper and ferrous sulphates are added. The catalytic effect is found to be greater than that calculated from the effects of the catalysts when used singly. This is shown by the following table:—

Molecular Concentration of the Catalyst.	Acceleration (Obs.).	Acceleration calc.).
$\frac{1}{32000}$ $CuSO_4$ + $\frac{1}{16000}$ $FeSO_4$	400	158
,, ,, + $\frac{1}{32000}$,,	238	99
,, ,, + $\frac{1}{64000}$,,	160	70
,, ,, + $\frac{1}{128000}$,,	108	57
$\frac{1}{32000}$ $FeSO_4$ + $\frac{1}{16000}$ $CuSO_4$	365	131
,, ,, + $\frac{1}{32000}$,,	238	99
,, ,, + $\frac{1}{64000}$,,	180	80
,, ,, + $\frac{1}{128000}$,,	141	69

Another point to be remembered in connection with catalytic actions is, that a substance which is a catalyst in one reaction is not necessarily a catalyst in another similar reaction. Thus, copper sulphate does not act catalytically in the oxidation of potassium iodide by means of bromic acid: molybdic acid is a very strong catalyst in the reaction just mentioned, but it has no catalytic effect in the reaction between potassium persulphate and potassium iodide.

In some cases the substance formed during the reaction acts catalytically. This is well seen in the case of the titration of oxalic acid by means of permanganate. When the first lot of permanganate is run into the oxalic acid solution, it is often noticed that the liquid becomes coloured a deep pink, which colour suddenly disappears. If more of the permanganate is then run in, the decolorisation of the latter is practically instantaneous so long as any oxalic acid is left, although theoretically, as the end point is approached, the reaction should proceed much more slowly than at first. The explanation of the observed phenomena is, that the manganese sulphate formed during the course of the reaction acts as a catalytic agent. When first the permanganate is run in to the oxalic acid, there is no manganese sulphate present, and the reaction proceeds very slowly. So soon as the least amount of the manganese sulphate has been formed, it begins to act catalytically and accelerates the reaction; this leads to the formation of more sulphate and consequent increase of the accelerating effect, since this is proportional to the concentration of the catalyst, which keeps increasing as the reaction proceeds.

All catalytic reactions are not so readily measured as the one just described (oxidation of potassium iodide by potassium persulphate). This is especially the case with a number of the reactions which are made use of in the manufactures. However, progress is being made in this direction, and very recently a paper was published by Bredig and Brown on the catalytic oxidation of organic substances by means of concentrated sulphuric acid. In the present method of making indigo, the first step is the oxidation of naphthalene by means of hot concentrated sulphuric acid in the presence of mercury. A similar method of oxidation is also used in the estimation of nitrogen according to the Kjeldahl method; instead of mercury, potassium sulphate or phosphorus pentoxide may be used. Bredig and Brown have made quantitative measurements of the rate of oxidation of aniline sulphate and naphthalene, by measuring the velocity with which the gases sulphur dioxide and carbon dioxide

* This denotes the time necessary for the reaction to have proceeded to a definite limit, the same in each case.

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are evolved. The catalytic effects of mercury, added either in the form of mercurous or mercuric sulphate, were especially studied: either sulphate was found to work equally well. In this case also it was found that the acceleration produced was proportional to the quantity of mercury. To give an idea of the effect of the mercury it may be stated that ½ per cent. of mercury trebled the reaction velocity. In the case of the oxidation of aniline sulphate, the following table gives an idea of the effects of adding different salts. Equivalent quantities of the salts were used, and the time found for the evolution of 24 cc. of gas, the temperature being kept constant at 270°C. Without the addition of a catalyst 208 minutes were necessary. The times are given in minutes :—

Mercurous sulphate . . .	13·8 minutes.
Copper sulphate	17·3 ,,
Ferrous sulphate	142 ,,
Nickel sulphate	160 ,,
Potassium sulphate . . .	170 ,,
Cobalt sulphate	172 ,,
Magnesium sulphate . . .	183 ,,
Phosphorus pentoxide . .	198 ,,
Manganese sulphate . . .	200 ,,
Cadmium sulphate . . .	221 ,,

Copper sulphate is thus a good catalytic agent, but potassium sulphate and phosphorus pentoxide have not very much effect. This does not seem to be in accordance with practice, since the two latter substances are found to shorten the time of oxidation very considerably. There is in reality no contradiction; in the course of an analysis no attempt is made to keep the temperature constant, and the addition of potassium sulphate or phosphorus pentoxide causes the reaction mixture to boil at a much higher temperature than it would do in the absence of these substances. A higher temperature means a greater velocity, and hence the practical use of the substances. In this case also it was found that the acceleration produced by a mixture of mercurous and copper sulphates was much greater than the sum of the individual accelerations.

The fact already referred to, that a substance which is a good catalyst in one reaction is not necessarily so in another, is well shown in the present case. Copper is much less active than mercury in the oxidation of naphthalene; the times for the evolution of the same volume of gas are 126 and 41 minutes respectively. Thus it would not be practicable to replace mercury by copper in the commercial process for the oxidation of naphthalene.

In organic chemistry, such processes as that of chlorination are very important. The use of substances as catalysts is very common in such cases. Let us, for example, consider the action of chlorine on benzene. If a solution of chlorine in dry benzene is made, it is found that the action of the chlorine on the benzene is very slow indeed in the absence of catalysts, including light among catalysts. If, however, so-called "chlorine carriers" are added, such as iodine chloride, tin tetrachloride or ferric chloride, the reaction readily takes place; light also has a catalytic effect. In this case there is not, as in the previous examples, one reaction only, but it is possible that substitution, addition, or both, may take place, as follows :—

$$C_6H_6 + Cl_2 = C_6H_5Cl + HCl.$$

$$C_6H_6 + 3Cl_2 = C_6H_5Cl_6.$$

Slator, by an investigation of the velocity of the reaction, was able to show that, with iodine chloride as the catalyst, 70% of the chlorine takes part in the substitution reaction, whilst the remainder combines additively. With tin tetrachloride and ferric chloride the substitution reaction alone takes place, so that in this case we have the interesting result that the effect of different catalysts on the same reaction is not necessarily of the same kind. Also, it was found that the accelerating effect due to a mixture of iodine chloride and tin tetrachloride is approximately equal to the sum of those due to the agents acting separately. Under the influence of light, without catalytic agents, the addition reaction alone occurs.

Another very important reaction in organic chemistry is that which bears the name of its discoverers, *viz.*, Friedel and Crafts. In this reaction aluminium chloride acts as a condensing agent. Thus, in the presence of aluminium chloride, benzene and ethyl chloride act on each other with the formation of the ethyl derivative of benzene. One point in which the aluminium chloride seems, in these reactions, to differ fundamentally from the catalysts which we have so far been considering, is that a small quantity is not sufficient to induce reaction between large quantities of the reagents; and, so far, this difference in behaviour has not been satisfactorily explained. This reaction has been thoroughly investigated, both by organic and by physical chemists. The former have brought forward the view that intermediate double compounds, with $Al Cl_3$, are formed during the course of the reaction, and the formation of these compounds enables the reaction to proceed. In support of this

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view several intermediate compounds have been isolated by different chemists. The physical chemists have arrived at the same conclusion from a study of the velocity of the reaction. Similar results were obtained for the action of ferric chloride. It is possible that the action of these two chlorides, in inducing the Friedel-Crafts reaction, differs from other cases of true catalysis only in the accident that these reagents combine with certain of the substances produced during the reaction, and are thus removed from the system.

(To be continued.)

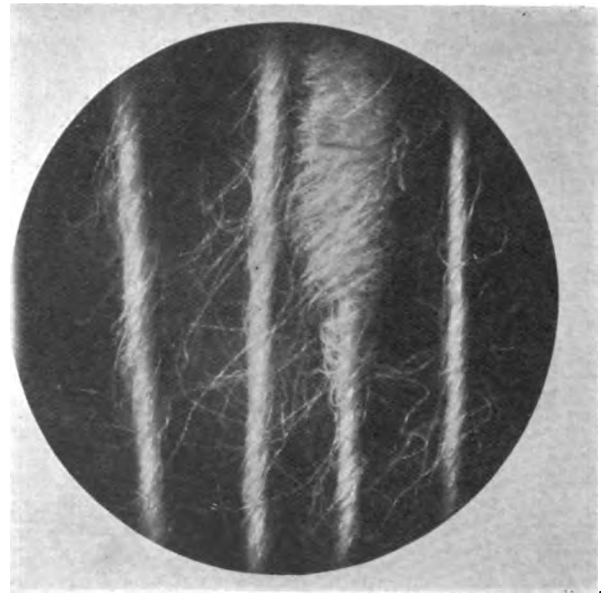
YARN IMPERFECTIONS.

By WM. L. HANNAN, Author of "The Textile Fibres of Commerce."

THE cotton shortage has caused many enquiries to be made as to whether some other fibre could not be found to take the place of that of cotton, but so far, without success.

If ever there was a time for a new fibre to be demanded, it is certainly just now. Liverpool and Manchester would gladly welcome any such new fibre, that could serve as a real substitute for cotton fibres or lint. Most of the cloth sold on the Manchester Exchange is made of cotton yarns, and these in their turn are made of lint fibres, twisted together by the aid of spinning machinery.

The accompanying illustration represents both good and bad yarn samples. Of the four yarns illustrated, three are fairly typical of a covering yarn, and the one that seems to be swollen is an instance of imperfection in the yarn structure.



This imperfection is known on change as a "cracker." Whenever crackers are present in yarns, they show that the yarn itself is faulty: that the cloth into which it is woven will also be faulty; and that the dyeing of the cloth and its finishing will entail increased expense. The presence of crackers in the cloth will appear almost like loops twisted up into little conical lumps of fibres.

Crackers reduce the strength of yarns. Short, snarly loops often accompany yarn crackers; and although such snarls, when simple, may be stretched out, yet breakages are often the result of these irregularities. Cloth merchants abhor them, spinners and directors regard them with as much disfavour as the boll weevil itself.

Even when a cracker is stretched out, it almost always leaves a tuft of fly, and the spaces between the tufts are cloudy and of dull white colour, a sure sign that the yarns will be irregular and untrustworthy when used in the weaving process.

A cracker is generally caused by want of skill in mixing the fibres of cotton, by the mixing together of unequal lengths. In the processes of drafting and hoisting, the fibres which form the core of the yarn are held in position longest, and form the screw ling of the yarn: the shorter fibres are released the earliest in the yarn structure, and give a loose, hayband-like appearance to the yarn as shown in the photo-micrograph illustration.

The proper build of yarns, and the terminology used either in a rough-and-ready way, or in a scientific manner, cannot be made too expressive, or too plain between the buyer and the seller of yarns, since lack of definiteness in the terms used may sometimes lead to costly legal proceedings.

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THEORY OF STRUCTURAL DESIGN.

PART VII.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

Nth Moments and Nature of Units.

IN the May issue of this magazine an endeavour was made to show that in the mechanics of structures the moments of inertia employed have nothing substantially in common with the inertia or inertness of matter; and the June issue contained examples of their use and purpose. Those desiring a thorough grasp of the inner meaning and true import of these constants will find it necessary to pursue their studies a little further, especially if the ability to calculate the necessary constants for any complex or compound section is aimed at.

Let b = breadth of beam in ins.
„ d = depth of beam in ins.
„ f = safe working stress on extreme fibres, in tons per sq. in.
„ f_x = stress at any distance x from neutral axis.
„ y = distance of extreme fibres from neutral axis.
„ p = stress at one inch from neutral axis.
„ x = distance of the centre of any strip from the neutral axis.

Let the section of the beam be divided into a great number of horizontal strips each of thickness = h. As the stress varies in intensity between the neutral axis and the extreme fibres, we can only assume that the stress is constant or uniform over a strip, if that strip is very narrow. Similarly, the leverage arm can only be assumed to be the same for every part of a strip, if the latter be very narrow.

The total moment of resistance of the beam will be the sum of the moments of resistance of all such strips as $b\,h$.

The intensity of the stress at $x = f_x$; and since $\frac{\text{one inch}}{x \text{ inches}} = \frac{p}{f_x}$, we know that $f_x = p\,x$.

The total stress on any strip will be $= b\,h.p\,x$.

The leverage arm = x, and the moment of the stress will be $= b\,h\,p\,x^2$

$= p.b\,hx^2$ (Eqn. XXV.)

Equation XXV. shows us that the moment of resistance of a layer at any distance x can be found by multiplying the stress at unit distance, by the product of the area of the strip, and the square of the distance of the strip from the neutral axis.

If an area such as $b\,h$ be multiplied by x, the product is spoken of, by mathematicians, as the "first moment of an area." If an area such as $b\,h$ be multiplied by the square, or second power, of the distance x, the product is called the "second moment of the area." Similarly, $b\,h\,x^n$ is called the n^{th} moment of an area. If the area be expressed in square inches, and if the distance x be also in inches, $b\,h\,x^2$ will be in inches to the fourth power.

Of course, strictly speaking, we cannot really multiply inches by inches, any more than we can multiply tons by tons.

What is 20 tons × 2 tons? It is 40——, but 40 what? It is 40 tons^2; but what is that? Can you imagine the weight, size, or shape of 1 ton^2?

How then can we multiply 3 inches by 3 inches?

Ten inches × ten inches = 100 square inches, we say; but this is only a short and very convenient way of stating that the area required is 10 × 10 times greater than the area enclosed by a square of one inch side.

Although a cube of one inch side has been adopted as a unit of volume, it does not follow, when N $(inches)^3$ occurs in an equation, that this quantity is necessarily a volume. N $(inches)^3$ may represent the first moment of an area, or may represent a section modulus.

Similarly, 12 pound-inches is not necessarily the measure of a tendency to rotation. It may refer to the energy spent in lifting a weight of 2 lbs. through a vertical height of 6 inches.

In this last case we do not really multiply inches by pounds. What we actually do is to multiply the number representing the inches by the number representing the pounds; and all that our answer tells us is that the energy spent is 6 × 2 times as great as the energy spent in lifting 1 pound through 1 inch.

We cannot see, weigh, or touch an inch-pound. It is merely a unit derived from simpler units, whereby we may measure the comparative magnitude of certain tendencies or effects.

As a matter of convenience, it is becoming customary to refer to energy as foot-lbs. and inch-lbs., and to write pound-feet and pound-

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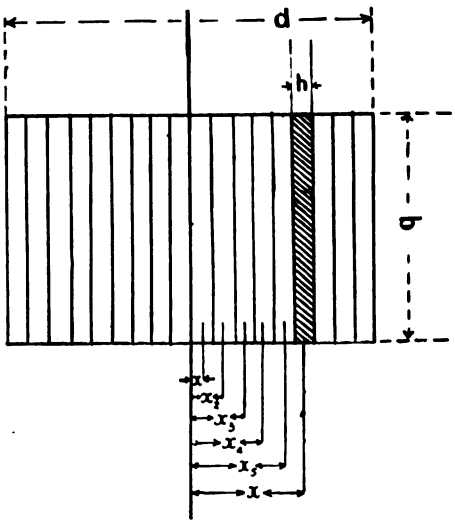

FIG. 38.

inches when we refer to turning moments. Now that the knowledge of compound and abstract units is fresh in the student's mind, perhaps he will more clearly perceive that the second moment of an area, or *ins.*[4] is not a magnitude capable of physical embodiment; and that 1 inch to the fourth power is an abstract magnitude or unit which we have expressed in terms of simpler units.

Now that the mathematical significance of the $p\ b\ h\ x^2$ (Eqn. XXV.) has been discussed, we shall write down the moment of resistance of several consecutive layers (Fig. 38), with a view of discovering the total moment of resistance.

The total moment of resistance of the section

$$= p\ b\ h\ x^2 + p\ b\ h\ x_2^2 + p\ b\ h\ x_3^2 + p\ b\ h\ x_4^2 + + \text{etc.}$$

$$= p\ [b\ h\ x^2 + p\ b\ h\ x_2^2 + b\ h\ x_3^2 + b\ h\ x_4^2 + + \text{etc.}] \quad \text{(Eqn. XXVI.)}$$

We see, then, that the total moment of resistance = the stress at unit distance multiplied by the sum of all such terms as $b\ h\ x^2$.

It is to be borne in mind that these results are based on the assumption that the strips are infinitely narrow.

Perhaps it can be realised that if the strips were really infinitely narrow, and therefore infinitely numerous, all the paper available would not be sufficient to contain the whole of the terms; yet the use of the higher mathematics enables us to write down the exact answer practically upon inspection. If each narrow strip of area in Fig. 38 be multiplied by the square of its distance from the neutral axis, and all these products be added together, the sum will approach nearer to $\frac{1}{12}\ b\ d^3$ as the strips are taken of less thickness. This $\frac{1}{12}\ b\ d^3$ is the geometrical constant which usually mystifies students under its deceptive name of *moment of inertia*, and is represented by the letter I.

In general terms I have described the arguments that underlie the concise symbols of the theorist's equations; but I must refer the student to the many excellent existing engineering pocket-books for complete tables of moments of inertia, and to the mathematical text-books for the proofs of the same.

The moment of inertia, or value of I, for certain complex sections, can very frequently be found by very simple means. For instance, the moment of inertia for a rolled steel joist may be obtained by taking the value of I for the enclosing rectangle, and then deducting the value of I for the shaded portion shown in Fig. 39. For this section,

$$I = \tfrac{1}{12}\ B\ D^3 - \tfrac{1}{12}\ b\ d^3$$

$$= \frac{B\ D^3 - b\ d^3}{12} \quad \text{(Eqn. XXVII.)}$$

Similarly, for the channels shown in Fig. 39,

$$I = \tfrac{1}{12}\ B\ D^3 - \tfrac{1}{12}\ b\ d^3$$

$$= \frac{B\ D^3 - b\ d^3}{12}$$

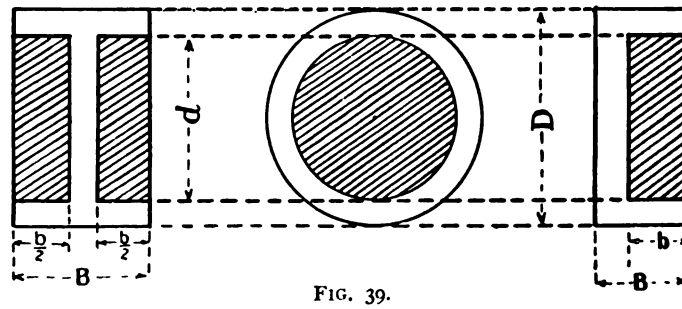

FIG. 39.

For the hollow circular column section in Fig. 39,

$$= \frac{\pi}{64}\ D^4 - \frac{\pi}{64}\ d^4$$

$$= \frac{\pi}{64}\ (D^4 - d^4)$$

(Eqn. XXVIII.)

For a rolled steel joist with the neutral axis coincident with the centre line of the web, we can obtain the value of I by dividing the

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section into three rectangles and adding the values of I for these three component parts.

For sections built up of rolled steel joists with equal flange plates top and bottom, we can obtain the value of I as follows:—

Let A = area of top or bottom flange plate (in square inches).

„ r = distance between centre of gravity of joist and centre of gravity of top or bottom flange plate (in inches).

The value of I for the top flange with respect to the neutral axis of the complete section

$$= A\,r^2$$

This is the "second moment" of the flange area; but I must hasten to add that it is only approximately correct, inasmuch as we have assumed that the whole of this flange area acts at the distance r, an assumption which is not strictly in accordance with the facts. The value of I for the bottom flange is the same as for the top flanges. Therefore, I for flanges is taken as

$$= 2\,A\,r^2$$

To find the value of I for the complete girder we should add I_j, or the value of I for the joists to the above product, then the total value of $I = I_j + 2\,A\,r^2$

(Eqn. XXIX.)

Equation XXIX. will be found very useful, since it enables us to find I for these compound sections without recourse to the more troublesome "Theorem of parallel axes."

$I_j + 2\,A\,r^2$ will be very slightly under the true result; but the error is on the safe side.

(To be continued.)

CITY AND GUILDS EXAMINATION QUESTIONS (1904).

ELECTRIC LIGHTING AND POWER TRANSMISSION, ORDINARY GRADE.

(Concluded from TECHNICS, *page* 609, *June*, 1904.)

7. The resistance of a D.C. armature, measured from opposite commutator sectors, is 0·013 ohm before running. After a six hours' run at full load the resistance is again measured and found to be 0·0147 ohm. What is the average temperature rise in the windings?

The temperature coefficient of copper (*i.e.*, the increase of resistance per degree Centigrade rise of temperature for each ohm at 0°C) is equal to 0·0043. We may assume that this value is equal to the increase of resistance per degree Centigrade rise of temperature, for each ohm at the initial (unknown) temperature.

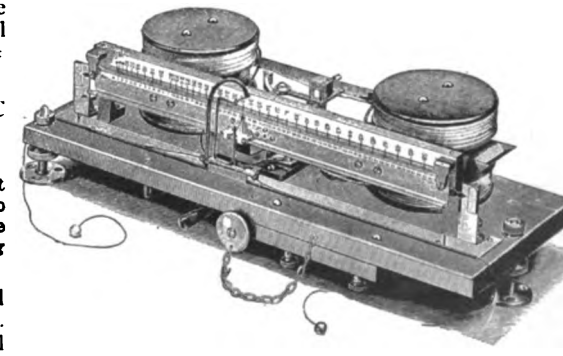
Then the increase of resistance of 0·013 ohm, per degree Centigrade rise of temperature = 0·013 × 0·0043 = 0·0000559 ohm. Actual increase of resistance = 0·0147 − 0·013 = 0·0017 ohm.

$$\therefore \text{temperature rise} = \frac{0{\cdot}0017}{0{\cdot}0000559} = 30{\cdot}4^{\circ}\text{C}$$

$$= 54{\cdot}7^{\circ}\text{F.}$$

8. Describe in detail the Kelvin Current Balance, and state what precautions have to be taken to ensure that balances for large currents should read correctly on alternating current circuits.

The Kelvin Current Balance is a standard instrument for measuring electric currents. Its principle of action depends on the mutual forces called into play between movable and fixed portions of an electric circuit traversed by a current. The shape chosen for the mutually-influencing portions is circular, and each such part is termed an ampere-ring. Each movable ring is actuated by two fixed rings—all three approximately horizontal. There are two such groups of three rings, two movable rings attached to the two ends of a horizontal balance arm; pulled, one of them up and the other down, by a pair of fixed rings in its neighbourhood. The current is in opposite directions through the two movable rings to practically annul disturbance due to horizontal components of terrestrial or local magnetic forces. The balance arm is



THE KELVIN CURRENT BALANCE.

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supported by two trunnions, each hung by an elastic ligament of fine wire, through which the current passes into and out of the circuit of the movable rings.

In all the balance instruments in which the movable ring is between two fixed rings, the mid-range position of each movable ring is in the horizontal plane, nearly midway between the two fixed rings which act on it. The current goes in opposite directions through the two fixed rings, so that the movable ring is attracted (say) by the upper fixed ring, and repelled by the lower ring. The position of the movable ring, equidistant from the two fixed rings, is a position of minimum force; the sighted position, for the sake of stability, is above it at one end of the beam and below it at the other, in each case being nearer to the repelling than to the attracting ring by such an amount as to give about two-tenths per cent. more than the minimum force. The balancing is performed by means of a weight which slides on an approximately horizontal graduated arm attached to the balance: there is a trough fixed on the right-hand end of the balance, into which a proper counterpoise weight is placed, according to the particular sliding weight in use at any time. For the fine adjustment of the zero, a small metal flag is provided, as in an ordinary chemical balance. This flag is actuated by a fork having a handle below the case. To set the zero, the left-hand weight is placed with its pointer at the zero of the scale, and the flag is turned to one side or the other, until it is found that, with no current going through the rings, the balance rests in its sighted position.

Instruments used to measure large alternating currents are arranged so that the main current through each circle is carried by a wire rope of which each component wire is insulated by silk covering, or otherwise, from its neighbour, in order to prevent the inductive action from altering the distribution of the current across the transverse section of the conductor.

9. It is required to raise water out of a mine 800 feet deep, at the rate of 8,000 gallons per hour. If the combined efficiency of pump and D.C. motor is 58 per cent., and 10 per cent. is lost in pipe friction, what current would be required with 500 volts at motor terminals?

1 gallon of water weighs 10 lbs.

Thus power usefully employed, in ft.-lbs. per min.,

$$= \frac{8{,}000 \times 10 \times 800}{60} = 1{\cdot}067 \times 10^6 \text{ ft.-lbs. per min.}$$

This is equivalent to

$$\frac{1{\cdot}067 \times 10^6}{3{\cdot}3 \times 10^4} = 32{\cdot}3 \text{ H.P.}$$

$$\text{or } 32{\cdot}3 \times 746 = 2{\cdot}4 \times 10^4 \text{ watts.}$$

Let P be the power in watts, supplied at the motor terminals. Then 0·58 P is usefully employed by the pump; but since 10 per cent. of the power used by the pump is lost in pipe friction, the power actually used in raising the water is 0·9 × 0·58 P = 0·52 P. Thus

$$0{\cdot}52\ P = 2{\cdot}4 \times 10^4 \text{ watts;}$$

$$\therefore P = \frac{2{\cdot}4 \times 10^4}{0{\cdot}52} = 4{\cdot}63 \times 10^4 \text{ watts.}$$

Let C be the current supplied to the motor; then

$$C \times 500 = 4{\cdot}63 \times 10^4 \text{ watts.}$$

$$C = \frac{4{\cdot}63 \times 10^4}{500} = 92 \text{ amperes.}$$

10. What is meant by the self-induction of an alternator armature, and how would you measure it? State clearly what instruments you would use, and what precautions you would take in making the measurements.

The self-induction of the armature, or the armature inductance of an alternator, is that property of the winding which gives rise to an E.M.F. of self-induction when the armature is traversed by an alternating current. In magnitude it is that quantity which must be multiplied by the time rate of change of the current to produce the E.M.F. of self-induction of the armature; or what comes to the same thing, it is the total number of linkages made by the magnetic flux (measured in *webers* or 10^8 C.G.S. units) with the turns of wire forming the armature winding when there is a current of one ampere traversing the armature. It may be determined by making the two following tests:

1. Observe the drop in volts which occurs when a known continuous current C is sent through the armature: if l_c be the drop in volts, the resistance of the armature will be

$$r_a = \frac{l_c}{C} \text{ ohms.}$$

2. Send an alternating current of strength C and at the nominal frequency, and again observing the drop in volts, l_a; the impedance of the armature will be

$$\text{Impedance} = \frac{l_a}{C}$$

$$= \sqrt{r_a^2 + (2\pi f L)^2}$$

in which f is the frequency, and L is the quantity which is required. The voltmeter used should be of the electrostatic type, and the ammeter should be calibrated to indicate the current at the proper frequency. It is obvious that the magnetic flux giving rise to this inductive effect should be due entirely to the current traversing the armature, and care should be taken to remove all other magnetic fields or external influences which might affect the result.

11. Describe accurately, but in as few words as possible, any good form of arc lamp with which you are familiar, making clear sketches of essential parts.

As details of arc lamp mechanism may be found fully described in most-text books on electrical engineering, it is unnecessary to describe them here.

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12. A choker, having an inductance of 0·05 henry, and resistance 0·5 ohm, is put in series with a non-inductive resistance of 10 ohms, and an alternating P.D. (sinusoidal) of 200 volts, 50 periods applied to the terminals; find the current in the circuit, and the P.D. on choker and resistance respectively.

Total resistance of choker and non-inductive resistance = 10·5 ohms.

Total inductance = 0·05 henry.

Total impedance

$$= \sqrt{(10\cdot5)^2+(2\pi\times50\times0\cdot05)^2}$$

$$= \sqrt{110\cdot2+246} = 18\cdot9 \text{ ohms.}$$

Current $= 200 \div 18\cdot9 = 10\cdot6$ amperes.

P.D. on non-inductive resistance

$= 10\cdot6 \times 10 = 106$ volts.

Impedance of choker

$$= \sqrt{0\cdot5^2+(2\pi\times50\times0\cdot05)^2}$$

$$= \sqrt{0\cdot25+246} = 15\cdot7 \text{ (nearly),}$$

$\therefore$ *P.D. on choker* $= 10\cdot6\times15\cdot7 = 166$ volts.

The P.D. and current are in the same phase in the non-inductive resistance; in the choker, the current lags behind the P.D., the angle of lag θ being given by the equation—

$$\tan\theta = \frac{15\cdot7}{0\cdot5} = 31\cdot4$$

Thus the angle of lag in the choker is very nearly equal to $\pi/2$.

13. Define "magnetic-leakage co-efficient" as applied to a generator. How would you measure it in the case of a large machine? How is its value affected by loading the dynamo?

The magnetic-leakage co-efficient is the value of the ratio of the *total* magnetic flux traversing the cores of the field magnets to the *useful* flux traversing the armature. Thus, if N_m = total flux of lines through the field magnet core, and N = magnetic flux through the armature, then

$$\frac{N_m}{N} = \nu = \text{co-efficient of magnetic leakage.}$$

The value of ν may be determined by placing a single coil of wire around the middle of one of the limbs of the field magnets, and connecting the ends of this complete coil to the terminals of a ballistic galvanometer. If the circuit of the field magnets, whilst the normal exciting current is passing, be suddenly short-circuited, the extent of the kick of the galvanometer needle will be a measure of the flux within the core of the limbs, neglecting the residual magnetism. If the short-circuit be suddenly removed, so that the current again passes round the field magnets, the extent of the kick of the galvanometer will be equal in magnitude and opposite in direction to that obtained previously. The flux through the armature may similarly be obtained if the leads to the ballistic galvanometer be soldered to consecutive bars of the commutator, connected to that convolution of the armature winding which lies in the plane of commutation, and readings be taken as before. The co-efficient of magnetic leakage will then be the ratio of the extents of the two kicks. The value of ν is not constant, and depends upon the amount of current taken from the armature, since the demagnetising effect depends upon the armature current; consequently the value ν increases as the dynamo is loaded.

14. Give the formula expressing the relation between voltage, induction density, area of core, and number of convolutions of an alternating current transformer working at a given frequency. State clearly the meaning of each symbol used, and explain how and why the formula would be modified if the applied P.D. wave were "peaky" or "flat-topped."

The formula giving the effective E.M.F. induced in the winding of an alternating current transformer is

$$E = 4\cdot45 f B A S \times 10^{-8} \text{ volts,}$$

when the applied P.D. is sinusoidal. In this formula f is the frequency, B the number of lines of force per square cm. traversing the core, A is the area of cross section of the iron core of the transformer, and S is the number of convolutions forming the winding. 4·45 is a constant, which is obtained as follows:—By the laws of electromagnetic induction, the maximum value of the E.M.F. induced in the case of sinusoidal quantities is

$$E_{max.} = 2\pi f B A S \times 10^{-8} \text{ volts,}$$

but the virtual or $\sqrt{\text{mean square}}$ value of a sinusoidal quantity is $\frac{1}{\sqrt{2}}$ times the maximum value, therefore

$$E = \frac{2\pi f B A S \times 10^{-8}}{\sqrt{2}} = \sqrt{2}\pi f B A S \times 10^{-8}$$

$$= 4\cdot45 f B A S \times 10^{-8}$$

The shape of the wave is an important element which affects the value of this constant. To show how the formula depends upon the shape of the wave, we may denote the ratio of the arithmetical mean of the instantaneous E.M.F.'s to the effective value of the same by the symbol F, and term it the *form factor*. Thus

$$F = \frac{E_a}{E_v}$$

where E_v is the effective or virtual value of the alternating E.M.F. The value of F varies for different E.M.F. waves, being unity for a rectangular wave and decreasing in value as the wave form becomes more peaky. Since for sinusoidal quantities $E_a = 0\cdot636\ E_{max.}$, and $E_v = 0\cdot707\ E_{max.}$, the value of the form factor for a sine wave is

$$F = 0\cdot9$$

and since the maximum value of the flux-density, B, varies directly as the form factor, the constant 4·45 increases as the wave becomes more peaky, and diminishes as the wave becomes more flat-topped.

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SOME NOTES ON "COPPING" IN THE SELF-ACTING MULE.

By W. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

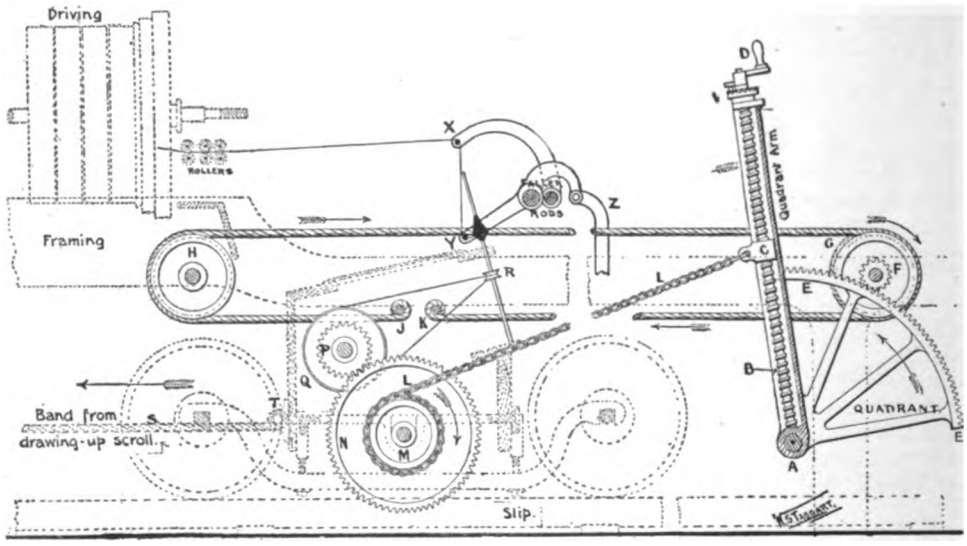

FIG. 1.

THE formation of the cop in a self-acting mule is primarily dependent upon a piece of mechanism called the Shaper. Associated with the action of the shaper, which merely gives the cop its special shape, we have another piece of mechanism called the Quadrant, which controls the speed of the spindle to suit the form given to the cop.

The shaper performs its functions through the medium of levers and wires called fallers and faller wires respectively. The wires, which run the full length of the mule carriage, act as guides for the yarn as it is being wound upon the spindle, and the positions of the wires are controlled from the shaper.

Two drawings are given in Figs. 1 and 2, which illustrate very clearly the combined actions of the quadrant and shaper. In Fig. 1, the quadrant and its connections are shown; from it we see how the spindle is driven during the inward run of the mule carriage. The sketch also illustrates the faller rods and the faller wires X and Y, and how these latter are worked through the faller leg H. The shaper itself, which actuates the faller leg, is given, in order to avoid complications, in a separate drawing (Fig. 2).

Fig. 2 gives us the long shaper complete. It consists chiefly of inclined surfaces A and

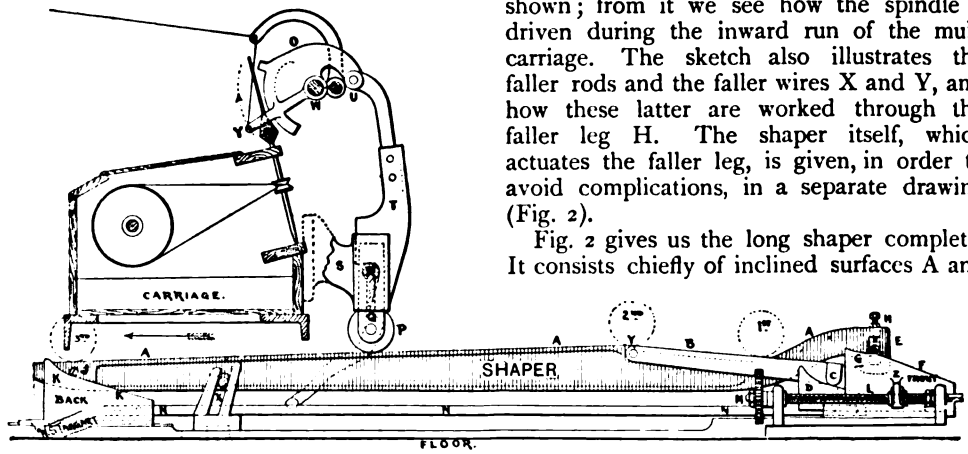

FIG. 2.

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B, of which the ends are supported on shorter inclined surfaces or plates. A bowl or narrow roller P travels along the inclined surfaces A and B, and as it rises or falls it moves the end U of the lever centred on the copping faller rod W in an upward or downward direction. The other end of the lever at Y carries the faller wire over which the yarn passes to the spindles. As the end U is depressed, Y is raised, and the yarn guided on to the spindle in accordance with the conformation and inclinations of the surfaces A and B of the shaper near the floor.

If Fig. 2 is carefully examined it will be noticed that, whilst the inclined surfaces A and B are the paths upon which the bowl P travels to and fro, these surfaces are in their turn supported on inclined surfaces at each end. These inclined plates are the chief features of the shaper, and upon their conformation depends the shape of the cop. A thorough understanding of them is both difficult and complicated, and would require several articles to thoroughly explain. Some idea of what they have to perform may be gathered from the sketches given in Figs. 3 and 4. Fig. 3 shows the spindle in its supports and natural position, whilst Fig. 4 represents an ideal cop with its chief features illustrated. The copping faller wire Y has to put on the different lengths of layers at AB, EC, and JG; it must also put on the crossed layer shown in dotted lines at the upper end of Fig. 4. When it is realised that all the layers from the first one at AB to

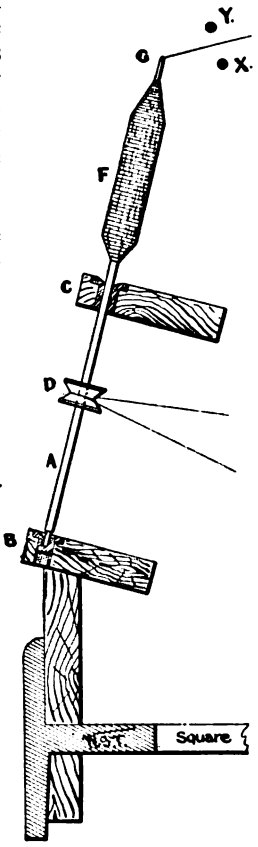

FIG. 3.

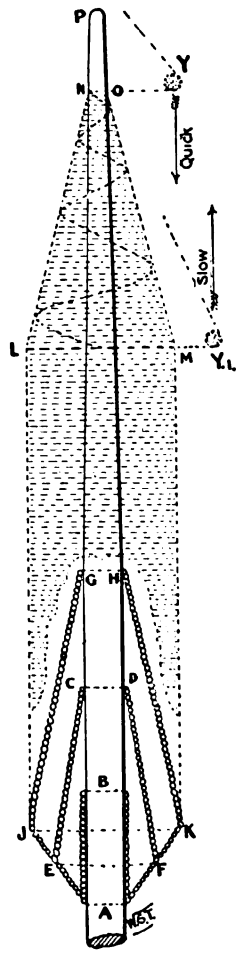

FIG. 4.

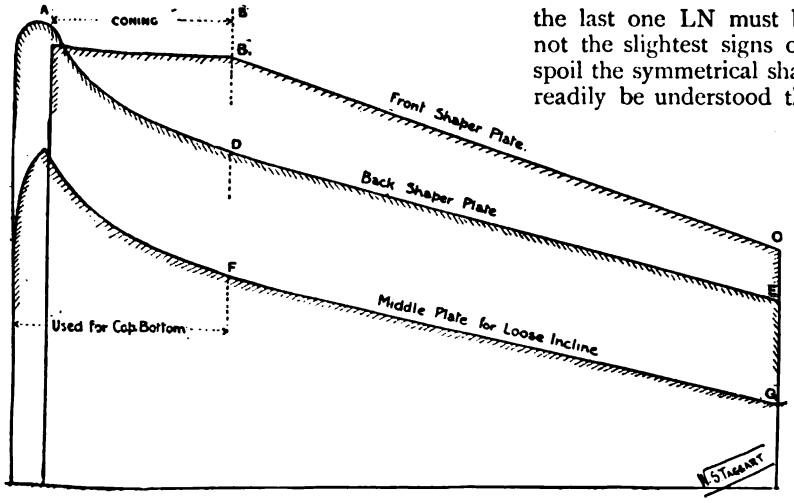

FIG. 5.

the last one LN must be wound on so that not the slightest signs of inequality exist to spoil the symmetrical shape of the cop, it will readily be understood that the plates of the shaper must be so perfectly formed as to eliminate the slightest signs of error.

A separate drawing of the three plates concerned is given in Fig. 5. The plates are shown superimposed so as to be easily compared, but their relative positions are clearly shown in Fig. 2. The portions

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of the plates marked "coning" are used for building up the lower part of the cop called the cop bottom; whilst the longer straight inclined portions are used for building the cop as it lengthens.

It would be interesting to give a full explanation of the reason for giving these plates the shapes they possess, but this must be left over for some future article, if the Editor permits. Our present object is to give a few practical hints on how badly formed cops can be improved if the shaper is found to be responsible for the faults. Whilst the notes will be brief, the student will, with the assistance of the drawings given, be able to reason out for himself why certain methods must be adopted to correct errors in the form of the cop.

A series of various shaped cops are shown in Fig. 6. The one marked A is assumed to be an ideal one, but all the rest are faulty in one or more particulars. The faults illustrated often occur in the self-acting mule, and are a constant source of trouble to the minder and overlooker.

Imperfections in the shape of the cop may be either local or general, a few cops only, or a whole set of them may be spoiled. This must be taken into account in looking for the cause. It must also be remarked that faulty cops are not of necessity the result of a faulty shaper. A ridgy cop, as at B, may be caused through the bowl P, in Fig. 2, being worn into flats, or it may not run on its full width the whole length of the shaper. The bowl in the faller leg slide may be uneven, or the studs carrying the bowls may be loose, and so cause ridges in the cop. New bowls and studs are the remedy. Ridges may also be caused by faller stands allowing the faller rods too much play. Another cause may be sought for in the shaper screw L, Fig. 2, as ridges will be formed if it moves the inclined plates in an irregular manner. If the ratchet wheel M,

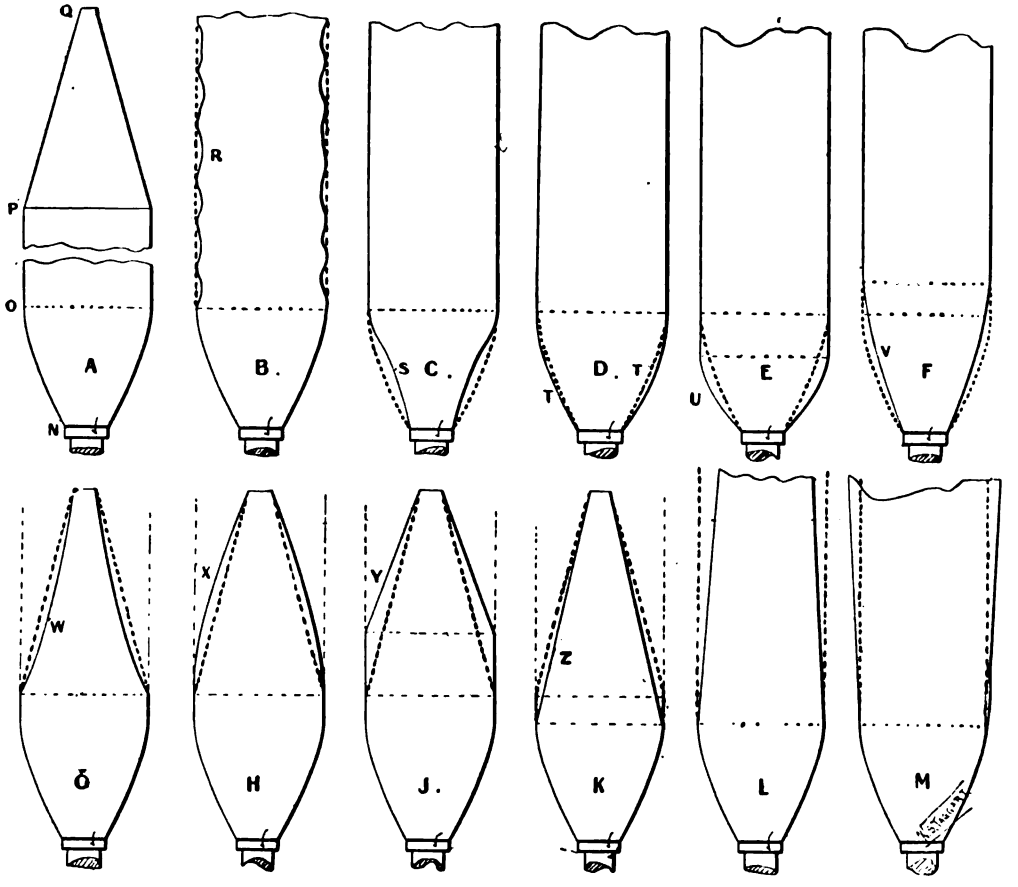

FIG. 6.

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Fig. 2, is not made to take its teeth regularly, we get ridges, so the action of the pawl must be carefully watched.

If cops are longer at the outer ends of the carriage than in the middle we get some cops longer than others; weak faller rods will cause this, or too heavy weights on the faller rods at the out end may be the cause. Soft cops, when not desired, may be due to the spindles not being turned quickly enough; put the quadrant a tooth or so back as a remedy. If cops are too hard, set the quadrant a bit more forward. The driving strap on the headstock must also be clear of the fast pulley during winding, so note this in looking for a cause of the fault. The highest point of the shaper rail Y in Fig. 2 may be worn, and so cause soft cops. Loose back shafts, sticky faller rods, or loose couplings in either of these shafts will give soft cops. Bad nosing motions, as explained in the April number of TECHNICS, will also cause the upper portions of cops to be soft. Also examine the scrolls, and see if they are too big for the stretch or loose on the shaft; otherwise soft cops result either locally or through the mule.

Thick and soft cops may be formed through the counter faller being depressed too soon before locking, and a too slack or too tight backing-off chain will give similar results.

See that no waste or dirt is lying around the shaper or on the inclines: have all bolts screwed up, and no bearing with more play than necessary: no weights touching the floor, and all moving parts perfectly free from any fixed part of the machine.

If every care has been taken to find out the reason for a faulty cop before examining the shaper plates, we may then turn to them and seek the same there. Before filing, shaper plates have exact gauges, and templates are made to serve as a guide to the profile, so that nothing unnecessary is done. The slightest bit too much filed off often means new plates.

Several diagrams are given in Fig. 7 to assist in showing the points on the shaper that may cause the faults indicated in the cops in Fig. 6.

The ridgy cop B, Fig. 6, may be caused by an uneven surface of the plates, so file up perfectly level and parallel to the original incline of the plate or plates.

Faults in C and D, Fig. 6, can be corrected by filing away a little between the highest and lowest points of the coning portion of the plates for C, somewhere about B in No. 1 of Fig. 7; and filing a little off the highest and lowest points for D, as well as a parallel filing off the long incline of the plates.

Cop E in Fig. 6 can be corrected as shown in No. 2, Fig. 7: file a little off the lowest point of the coning, and go to nothing at the highest point. The remedy for F is the opposite to this, as shown in No. 3, Fig. 7; file off the required amount at the starting-point of the coning, and taper to nothing at the finishing point.

Cop G has a hollow chase; this means that the long part of the shaper rail must be filed flatter at its highest point.

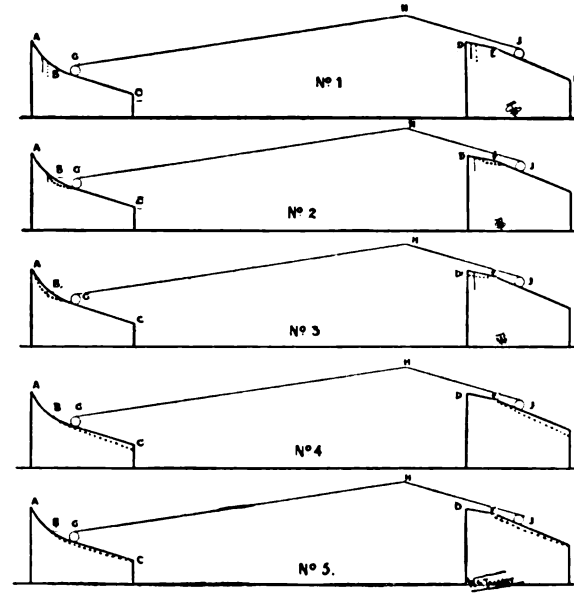

FIG. 7.

In the case of cop H we simply alter the distance between the highest and lowest points of the shaper rail by means of the adjusting screw.

Specimens J and K may be altered in a similar manner.

Cops L and M are corrected by filing the plates as shown in No. 4 and No. 5 of Fig. 7. Before filing, however, see that the faller leg top centre is in a line with the faller rod and faller wire when the faller wire is at the middle of the spindle; otherwise tapered cops will result from this cause independently of the shaper.

If students are really desirous of thoroughly understanding the shaper, they will make for themselves cardboard or wood models, and

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by means of these it will be an easy matter to reason out the effect produced by any of the alterations suggested above. They will learn more from an hour's study of such a model than from weeks of study given to a description. Sketches are also far more valuable than a written description in such cases, and if once the habit of making a rough sketch of a piece of mechanism is formed, it will be found that explanations become almost unnecessary, or at the utmost a series of brief notes.

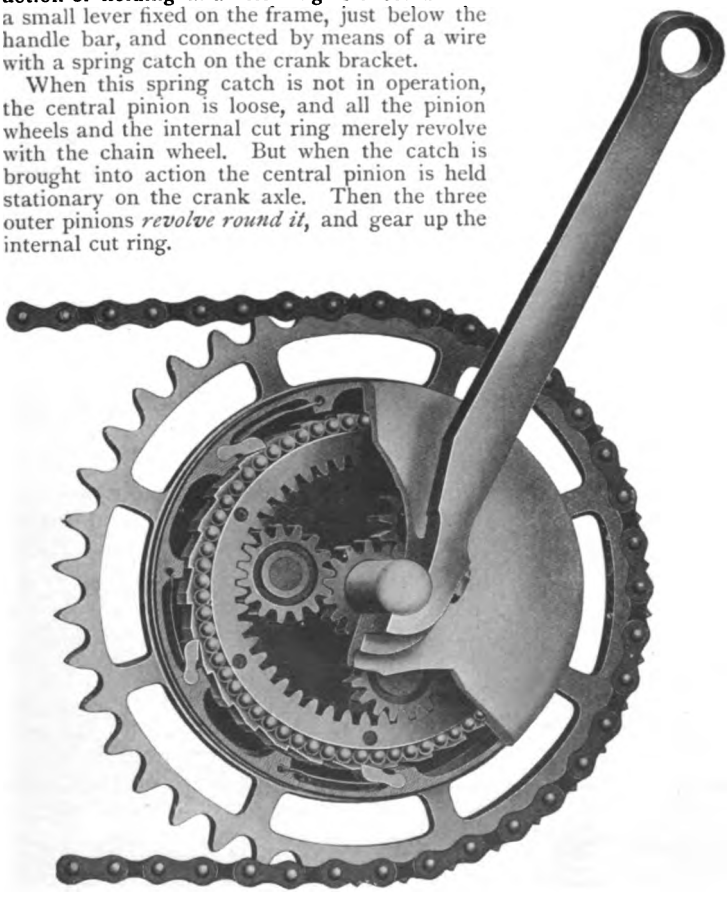
RECENT INVENTIONS.

TWO SPEED GEAR.

THE Sunbeam Two Speed mechanism is located inside the crank chain wheel. It consists of one central pinion wheel, and three small outer pinion wheels which gear into an internal cut ring. The change of gear is obtained by simply holding or releasing the central pinion. This action of holding and releasing is effected from a small lever fixed on the frame, just below the handle bar, and connected by means of a wire with a spring catch on the crank bracket.

When this spring catch is not in operation, the central pinion is loose, and all the pinion wheels and the internal cut ring merely revolve with the chain wheel. But when the catch is brought into action the central pinion is held stationary on the crank axle. Then the three outer pinions *revolve round it*, and gear up the internal cut ring.

The internal cut ring accelerates the speed of the chain wheel, and causes it to overrun the normal gear through a free wheel mechanism situated outside the internal cut ring. It will thus be seen that the gear is always in mesh, and the mere holding or releasing of the central pinion effects the requisite change.



THE "SUNBEAM" TWO SPEED GEAR.

A SIMPLE BUT TRUSTWORTHY GALVANOMETER.

A SIMPLE and very convenient astatic galvanometer is shown in the illustration p. 87. This galvanometer has been designed by Chas. A. West, B.Sc., A.R.C.S., Lecturer on Physics at the City of London College, and is intended for use in technical schools and colleges. It is made by the West London Scientific Apparatus Company, Deodar Road, Putney. The coil consists of a large number of turns of wire wound without bobbin, so that the wire is close to the needle. The astatic needle is very sensitive, and is supported from above by means of a pivot working in an agate cup. The advantages of this form of suspension over the ordinary fibre suspension are two-fold. In the first place, the suspension is very much less likely to be damaged; and if by any means the pivot is broken it is easily repaired. New pivots can be obtained at a trifling cost, and a new one can be inserted in

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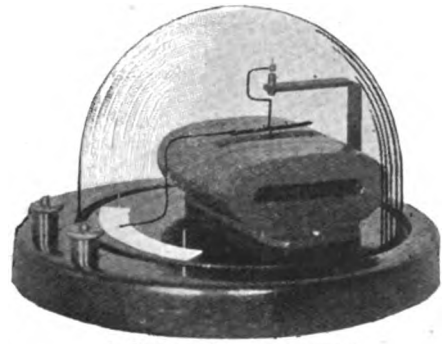
a few seconds. In the second place, the suspension is very short and, therefore, levelling screws are not necessary. Hence the instrument is very quickly adjusted for work. The galvanometer has been specially designed for use in experiments where small potential differences are dealt with, as in the measurements of resistances by means of the Wheatstone bridge or metre bridge, the measurements of electro-motive forces by the potentiometer, experiments in thermo-electricity, and simple induction experiments. If a piece of German silver wire is attached to one terminal of the galvanometer and a piece of iron wire to the other, and the free ends twisted together, then if the junction of the two metals is held between the finger and thumb, the thermo-electric current produced will give a deflection of from ten to thirty degrees, according to the temperature of the room.



A Simple Galvanometer.

If a suitable shunt is used the neutral point and temperature of inversion can easily be illustrated by means of a couple consisting of copper and iron wires; the temperature of the hot junction being gradually raised by an ordinary Bunsen burner.

As the price is low and the workmanship good, this useful galvanometer should meet the needs of schools and colleges where a number of galvanometers of the same type are required.

REVIEWS.

Three-Colour Photography: Three-colour printing and the production of photographic pigment pictures in natural colours. By Arthur Freiherrn von Hübl, Colonel, Director of the Technical Section of the Royal Imperial Military Geographical Institute in Vienna. **Translated by Henry Oscar Klein.** pp. 148 (London: A. W. Penrose & Co., 1904).

This book should be welcomed by all interested in the subject of colour photography and printing. Although it has been written so as to be understood by those possessing but an ordinary acquaintance with science, yet it is by no means a mere popular treatise. Every point is treated with care and described with precision, so that the conscientious reader, before laying the volume down, will have acquired a good working acquaintance with the subject. In the introduction, a brief and lucid account is given of the various methods of colour photography. Lippmann's method depends on the formation of stratifications of reduced silver separated by the transparent gelatine of the photographic film; the colour observed is due to the same cause as the iridescent hues of mother-of-pearl. Wiener's method depends on the formation of pigmentary body colours, and can be explained as follows:—A substance sensitive to light can only be affected by the rays which the substance absorbs. Red light will have no effect on a red body, since a red body is one which reflects the red rays unaltered, but absorbs all other visible rays. If, therefore, a substance like silver sub-chloride is exposed to red light, it will change until it reaches a stage at which red light produces no further effect, *i.e.*, until it becomes red. The fugitive nature of the colours produced by Wiener's method constitutes the chief disadvantage of the process; but at present, rapid strides are being made to overcome this drawback, and a practical solution of the problem of colour photography may ultimately be arrived at along these lines. The more popular method of three-colour printing depends on the fact that any colour sensation whatever may be produced by a mixture of three spectral colours, sufficiently far apart in the spectrum. In some cases the "primary" colours red, yellow, and blue are combined in different proportions to produce the various natural colours; theoretically, green should be substituted for yellow. Three transparencies are printed from negatives made on plates of different colour sensitiveness. On one of these the yellow portion of the spectrum will not have acted, and we obtain a negative which is printed on a yellow transparency. Prints on the red and blue transparencies are obtained in a similar manner. If the three transparencies are combined, we obtain a combination picture which should be a reproduction of the original in its true colours. This brief sketch must serve to indicate the basis on which modern methods of photographing in colours have been built up. Full details are given in von Hübl's work, which is illustrated with coloured plates, and contains numerous diagrams and perhaps the most up-to-date account of the subject to be had in the English language. A good index is provided.

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The Management of Electric Tramways and Light Railways. By William R. Bowker, C.E. pp. xii. + 291. (London: E. and F. Spon, Ltd., 1904.) Price 9*s*. net.

In this volume the author deals with the subject of Electric Traction from a commercial and economic standpoint. There are many books from which valuable information as to motors, generators, track, etc., can be obtained, but the subject of practical management has not heretofore been dealt with in book form. Mr. Bowker deals with the aspect of the subject that presents itself to the business manager of an electric tramway company. Section I. is devoted to a consideration of the staff, rolling stock, and working and financial considerations. In Section II. we find a discussion of the possibilities of light railways, goods traffic, carriage of merchandise, terminal charges, economic considerations, compensation and combination, and the clearing house system. The subject of season tickets and workmen's tickets is dealt with in Section III.; this section contains a valuable collection of official reports from various companies. Section IV. deals with financial reports, tramway accounts, estimates of costs, specifications, Board of Trade regulations, etc. The book is well got up and contains a good index.

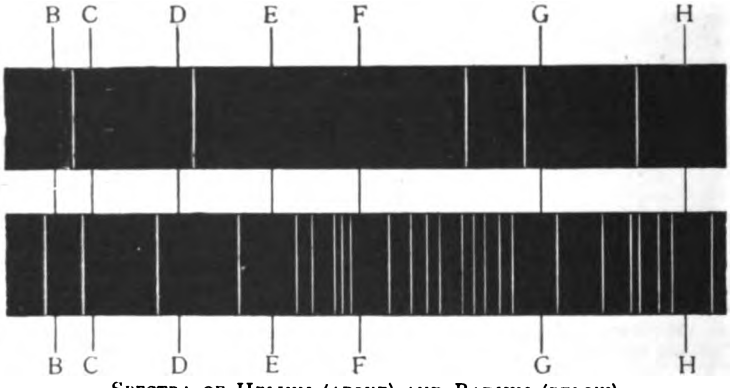
Radium and Other Radio-Active Elements: a Popular Account treated Experimentally. By Leonard A. Levy and Herbert G. Willis, pp. 105. (London: Percival Marshall and Co., 1904.) Price 2*s*. 6*d*. net.

There is some sort of fascination about radium which has enthralled the public fancy, and rendered every publisher anxious to issue a book on this interesting element. The subject, of course, can be treated from various standpoints. Messrs. Levy and Willis have written for the benefit of the intelligent reader who does not wish to go into mathematical subtleties or abstruse theories, but desires a general acquaintance with the work that has already been carried on, and that is now in progress. The book commences with a chapter on the discovery of radium, and succeeding chapters deal with the radium emanation, electric and magnetic effects, luminous and other allied effects, and chemical effects. In the sixth chapter a very detailed account of the effects of radium on animal life is given. This should be very useful to the general reader. The seventh chapter deals with radio-active substances other than radium, and includes accounts of uranium, thorium, polonium, actinium, and Hofman's radio-active metal. A few details of apparatus are given in an appendix. The book is well got up and contains several full-page illustrations on art paper.

Chapters on Papermaking. Vol. I. **Comprising a series of lectures delivered on behalf of the Battersea Polytechnic Institute, in 1902. By Clayton Beadle.** pp. 151. (London: H. H. Grattan, 1904).

Those interested in the manufacture of papers will find much valuable information in these lectures. There is, further, much that should receive attention from publishers and others who come under the head of "users of paper." Mr. Beadle treats the subject from a thoroughly scientific standpoint; he mentions many instances in which apparently insignificant causes have momentous results in the finished paper, and invariably passes from a scientific observation to a practical application of the same. The concluding words of the preface aptly explain the scope of the book:—

"Papermaking, like other progressive industries, is undergoing changes: what is new to-day will be old to-morrow; and lectures on papermaking must share a similar fate. But the subjects with which these lectures deal will remain with us, and will continue to engage the attention of the papermakers and papermaking chemists of the future."



Spectra of Helium (above) and Radium (below). (*From* "*Radium and Other Radio-Active Elements.*")

The Measurement of Volumes, with an account of new apparatus designed by S. Irwin Crookes, A.I.E.E., F.C.S. pp. 12. (Birmingham: Philip Harris & Co., Ltd., 1904.)

These few pages give an account of various simple appliances to be used in teaching mensuration to elementary students. Many of these appliances are both interesting and novel.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the* 10*th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

STEREOISOMERS.—Give, in extenso, the proofs of the following formulæ for the numbers of possible stereoisomers — optically active and inactive — of compounds containing a chain of carbon atoms united by single bonds.

n = number of asymmetric carbon atoms contained in the molecule of the substance.
N = total number of stereoisomers which may be divided into—
(*i*) the inactive non-decomposable modifications, and
(*a*) the active forms which occur in pairs (optical antipodes) of equal but opposite rotatory power. These active isomers lead to
$r = \frac{a}{2}$ inactive, decomposable racemic forms

First Class. n_1 even or odd.

R and R_1 denote the radicles at the ends of the chain and a and b those united to the intermediary carbon atoms of the chain.

Type $R - (^*C\ a\ b)_{1,\ 2,\ 3} - R_1$.;

$$N = 2^n,\ a = 2^n,\ i = 0$$

Second Class. n_1 even.

Type $R - (^*C\ a\ b)_{2,\ 4,\ 6} - R$;

$$N = 2^{n-1} + 2^{\frac{n}{2}-1}$$

$$a = 2^{n-1},\ i = 2^{\frac{n}{2}-1}$$

Third Class. n_1 odd.

Type $R - (^*C\ a\ b)_{3,\ 5,\ 7} - R$

$$N = 2^{n-1},\ a = 2^{n-1} - 2^{\frac{n-1}{2}},\ i = 2^{\frac{n-1}{2}}$$

N.B.—In second and third classes terminal radicles are alike, in class one they are different.

Founded on a statement in Landolt-McCrae's "Optical Activity and Chemical Composition," p. 61 (*Whittaker & Co.*).

In discussing this question it will be convenient to use a notation in which the signs of the different carbon atoms are determined by approaching them from the left-hand end of the chain only. Thus, if we approach the apex of a tetrahedron *vidê* the part of the chain on the left, we should observe the groups on the other three corners in the order, say, $a-b-X$ (X being the residue of the chain represented in the formulæ to the right) reading clock-wise (+) or counter-clockwise (−)

As is well-known, and as is easily seen by reference to a model, we reverse the "hand" if we approach from the opposite end of the chain, an atom wheel appears + from the left appearing − from the right and *vice-versâ*; in other words, if we turn the formula of a given compound so that the right end becomes the left, then we must reverse the sign of each carbon atom.

Now the criteria for the existence of an inactive, non-decomposable modification are, that the formula shall be symmetrical about the centre point and that each truly asymmetric carbon atom shall be balanced by another, symmetrically disposed and opposite in its effect, *i.e.*, if the two asymmetric atoms of such a pair are approached respectively from the nearest ends of the chain, one must be + and the other − ; hence if both are approached from the left, in accordance with our convention, both must be +, or both − . Such a formula, being symmetrical about its centre, represents the same substance if the sign of every carbon atom is reversed, because the resulting formula is the same as that which would be obtained if we turned the original one so that the right end became the left, reversing the sign of each carbon atom (see preceding paragraph).

In the first class, which may be represented—

$$R - C\ a\ b\ .\ .\ .\ .\ .\ .\ .\ .\ C\ a\ b - R_1$$

the system is not symmetrical about any point in the chain, so that no two carbon atoms can be equivalent, hence no inactive non-decomposable modification can exist;

$$(\therefore\ i = 0)$$

Starting with the carbon atom on the extreme left, it may be + or − (*i.e.*, two possibilities), the next one also provides two possibilities, or taken together, these two atoms provide 2×2 possibilities, each additional asymmetric carbon atom doubling the previous number of possibilities, hence the total number with n carbon atoms is $2 \times 2 \times 2\ .\ .\ .\ .\ .$ (n factors) $= 2^n$.

$$(\therefore\ a = 2^n, \text{ and } N = 2^n).$$

In the second class, which may be written—

$$R - C\ a\ b\ .\ .\ .\ C\ a\ b - C\ a\ b\ .\ .\ .\ C\ a\ b - R$$

the molecule is divisible into two parts between the two median carbon atoms, and the two portions, apart from steric considerations, are symmetrically disposed to the centre point, and each contains $\frac{n}{2}$ carbon atoms.

*C denotes asymmetric carbon atom.

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Consider first the active modifications. Here one, at least, of the asymmetric atoms and its equivalent must have dissimilar signs, as read from the left, or the molecule would be inactive (par. 3). Confining our attention to this pair, they will read + −, and when the molecule is turned so that the right becomes the left, the necessary inversion makes them still read + −. There is therefore a second way of writing this pair, namely − + which is not the same as the previous one; in other words, this pair alone presents two possibilities. Having once fixed the signs of this pair, every one of the other $n - 2$ groups C *a b* may be chosen + or − at will, so that each presents two possibilities, or in all 2^{n-2}, which, taken with the two which the original pair provided, gives altogether $2^{n-2} \times 2 = 2^{n-1}$

$$(\therefore a = 2^{n-1}).$$

Now consider the inactive modifications. Here if we fix the sign of any one carbon atom, that of the symmetrically disposed one must be the same (par. 3). Confining our attention to one pair first, these may be + +, which on turning round the formula gives − −; in other words, the first pair alone provides only one possibility; call this + +. This leaves $n - 2$ groups C *a b* which run in pairs, *i.e.*, there are $\frac{n}{2} - 1$ pairs which may be either + or − .

Hence each of the $\frac{n}{2} - 1$ pairs provides two possibilities, in all $2^{\frac{n}{2}-1}$, which gives us the total number of modifications, because the first pair dealt with provided only one possibility

$$(\therefore i = 2^{\frac{n}{2}-1}, \text{ and } N = 2^{n-1} + 2^{\frac{n}{2}-1}).$$

Third class. Write thus

$$R - C\,ab\,.\,.\,.\,C\,ab\,.\,.\,.\,C\,ab - R.$$

The central carbon atom, read from the left, may be + or −. Starting our investigation from this atom, we note it presents us with one possibility only, because if labelled +, and the formula then reversed, it becomes − automatically. Imagine it fixed so as to read +. There remain $n - 1$ groups C *a b*, each of which may read either + or −, presenting, therefore 2^{n-1} possibilities, so that the total number of different isomerides is $1 \times 2^{n-1}$ as the centre carbon atom only provided one possibility ($\therefore N = 2^{n-1}$).

Of these isomerides, those will be inactive in which the individuals of corresponding pairs have the same sign, hence here, to fix the sign of an atom on the left of the centre is to fix that of the corresponding one on the right. This then gives two possibilities for each of the $\frac{n-1}{2}$ pairs, in all $2^{\frac{n-1}{2}}$, which, for the reason given in the preceding paragraph, gives us the total number of inactive isomerides. (Note that in these cases the centre carbon atom is not an asymmetric one).

$$(\therefore i = 2^{\frac{n-1}{2}} \text{ and } a = 2^{n-1} - 2^{\frac{n-1}{2}}).$$

(It should be observed that we have exhausted all the possible cases of Class 3 by this process, for if we take the formulæ so obtained and turn them round so that the right end becomes the left, and change the signs of all the C *a b* groups, the formulæ so produced represent the same substances, whilst we automatically exhaust all the possible cases in which the centre carbon is −. Exactly similar considerations hold in case of the inactive modifications of Class 2).

HYDROXYMETHYLENE. — Give an account of Claisen's work on the hydroxymethylene compounds. —*Board of Education, Chemistry, Honours*, 1903 *and* 1904.

The hydroxymethylene compounds were obtained by acting with formic esters on compounds containing the group $CH_2{\cdot}CO$, with sodium or sodium ethoxide as a condensing agent. The elements of alcohol were thereby withdrawn, and the sodium derivative of the hydroxymethylene compound was produced as follows:

$$NaO{\cdot}C_2H_5 + H{\cdot}CO{\cdot}OC_2H_5 + \begin{matrix} CH_2{\cdot} \\ | \\ CO{\cdot} \end{matrix} =$$

$$\begin{matrix} NaO{\cdot}C : C{\cdot} \\ | \\ CO{\cdot} \end{matrix} + 2C_2H_5OH.$$

the principle being identical with that regulating the well-known synthesis of ethyl acetoacetate from acetic ester.

The hydroxymethylene compounds were isolated in various ways. Usually the sodium derivative was dissolved out by means of ice-water, and decomposed by addition of acetic acid. If sufficiently stable, they could then be collected by extraction with a suitable liquid; or at once obtained in a solid form. Some could not thus be isolated, as they at once underwent condensation; thus hydroxymethylene acetic ester changed to ethyl 1 : 3 : 5 benzenetricarboxylate

$$3\ HO{\cdot}CH : CH{\cdot}CO_2\,Et$$

$$= CH\begin{matrix} \diagup C(CO_2Et) = CH \diagdown \\ \diagdown C(CO_2Et) - CH \diagup \end{matrix} C{\cdot}CO_2Et$$

$$+ 3H_2O$$

whilst hydroxymethyleneacetone was easily converted into symmetrical triacetylbenzene.

The hydroxymethylene compounds thus obtained are distinctly acidic in character, and dissolve in aqueous solutions of alkali hydroxides, which is in accordance with the fact that they contain the group C = C·OH, also present in the acid, *enolic* forms of β diketones, etc., and in phenols. They exhibit most of the reactions of hydroxy compounds, affording benzoyl and acetyl derivatives without difficulty, and react with cold phenylisocyanate, forming carbamic esters. They afford characteristic copper derivatives, insoluble in water, but dissolved by organic liquids, and give red or violet colorations when their solutions in water or alcohol are mixed with a few drops of ferric chloride solution.

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Their properties and mode of origin links them with the "enolic" forms of β-ketonic acids, β-diketones, etc., and hence they would be expected to show the reactions of aldehydes, or even to be convertible into these by "tautomeric change."

$$HO{\cdot}CH : \overset{|}{C}{\cdot}\overset{|}{C}O \rightarrow O : \overset{|}{C}H{\cdot}\overset{|}{C}O.$$

In general, however, they are more stable than other classes of *enols*; nevertheless, they manifest some tendency, in certain instances, to pass into the "aldehydic" form, as is supposed to be the case with ethyl hydroxymethylenephenylacetate

$$HO{\cdot}CH : C(C_6H_5){\cdot}CO_2Et \rightarrow O : CH{\cdot}CH(C_6H_5){\cdot}CO_2Et.$$

In other cases the only evidence of aldehydic character is found in their reactions. For example, hydroxymethylene camphor yields an oxime without difficulty, and this is an aldoxime, as it easily loses water to form cyanocamphor

$$C_8H_{14}\begin{cases}CH{\cdot}C{:}N{\cdot}OH\\ |\\ CO\end{cases} \rightarrow C_8H_{14}\begin{cases}CH{\cdot}CN\\ |\\ CO\end{cases} + H_2O$$

with phenyl-hydrazine they act as might be anticipated if they were aldehydic in character, and give hydrazones which lose water, forming pyrazoles and pyrazolones.

The mode of preparation above given fails when applied to compounds which contain the groupings, $\cdot CO{\cdot}CH_2{\cdot}CO$ or $\cdot CO{\cdot}CH_2{\cdot}CN$, as for instance, β-diketones, β-ketonic esters, malonic esters and cyanacetic esters. A method of converting these in hydroxymethylene derivatives was also discovered by Claisen, and involves the following processes.

The compound is mixed with orthoformic ether and acetic anhydride, when, on warming, the following reaction occurs:—

$$EtO{\cdot}CH(OEt)_2 + CH_2(CO_2Et)_2 = EtO{\cdot}CH : C(CO_2Et)_2 + 2C_2H_5OH,$$

the alcohol being converted instantly into ethyl acetate by the condensing agent. The important products here are "ethoxymethylene" compounds, which are easily hydrolysed, in some cases by water alone, and in other cases by alkalis, the hydroxymethylene compound and alcohol being produced

$$EtO{\cdot}CH : C(CO_2Et)_2 + HOH = HO{\cdot}CH : C(CO_2Et)_2 + HOEt.$$

These hydroxymethylene compounds all contain the group

$$X = \overset{\cdot}{C}\diagdown\!\diagup C = CH{\cdot}OH \text{ or } \begin{matrix}X = C\\ Y = C\end{matrix}\!\diagdown\!\diagup C = CH{\cdot}OH$$

and differ from the former class, which contain only $X = \overset{\cdot}{C} - \overset{\cdot}{C} = CH{\cdot}OH$, in their extraordinary degree of acidity, being comparable in strength with many carboxylic acids, expelling carbon dioxide from solutions of sodium carbonate and dissolving in aqueous solutions of sodium acetate, although nearly insoluble in pure water. Their ethers, the "ethoxymethylene" compounds above mentioned, are highly reactive, the $\cdot OEt$ of the ethoxymethylene group being directly replaceable by $-NH_2$, etc, and broadly speaking, exhibiting the properties of the $\cdot OEt$ group of carboxylic esters.

BLEACHING COTTON SEED OIL.—I shall be very much obliged if you could tell me if there is any method known that will bleach cotton seed oil thoroughly and cheaply. Watts' Dichromate and all ordinary bleaching re-agents used for oils do not seem to bleach cotton seed a good white.

For the purposes of refining, cotton seed oil is seldom bleached, as it can be obtained colourless, or practically so, by other methods. The almost universal procedure is the alkali treatment, in which 10 to 15 per cent. of a solution of caustic soda (sp. gr. 1·06 to 1·10) is added to the oil at the ordinary temperature. The mixture is agitated and the temperature sometimes raised to 100—110° Fahr. The alkali combines with a red colouring matter present in the oil, and also saponifies a part of it. On standing, black "flocks" separate and deposit, leaving an almost colourless product. Where the oil is intended for technical applications, such as soap-making, and not for edible purposes, this process may be rendered more economical by carrying the alkali treatment only far enough to remove the greater part of the colouring matter, after which it is boiled with a solution of bleaching-powder, and then washed with dilute sulphuric acid. In this process the purified oil acquires an unpleasant taste and smell which cannot be removed. According to Braunt, the oil from the alkali treatment is obtained perfectly colourless in America by agitating with 2—3 per cent. fuller's earth and subsequent filtering.

According to Jolles and Wild, the oil may be bleached with a chromic acid mixture of 50 parts potassium bichromate, 100 parts sulphuric acid, and 500 parts water. Of this mixture, 6½ lbs. are required for every 100 lbs. of cotton seed oil, previously heated to 140° Fahr. The whole is kept stirred for an hour or so, and then washed free from acid, and clarified with animal charcoal.

A patent was taken out in 1901 (Eng. Pat. No. 11,419) for bleaching oils by causing them to circulate in a thin film exposed to the action of the light from arc lamps. There are, of course, many other chemicals that will bleach oil, but are quite out of the question in the case of such a cheap product as cotton seed oil.

INDUCTION MOTOR.—Draw and fully explain the circle diagram as used in connection with the design of polyphase induction motors. Construct the diagram for a 6-pole star-connected 3-phase motor having the data given below, and find the full load power-factor, stator current, and slip of the motor.

Rated output, 40 B.H.P. at 380 volts, 50 cycles.

No load current, 16 amperes at 380 volts, 50 cycles.

Short circuit (standstill) current, 310 amperes at 380 volts, 50 cycles.

Power absorbed at no load, 1,550 watts.

Power-factor of short-circuit current, 0·23.

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Resistance, terminal to terminal, of stator winding (hot) is 0·156 ohm.

The circle diagram of the induction motor, sometimes termed the Blondel-Behrend-Heyland diagram, is a beautiful graphical method of exhibiting the variations of the stator and rotor currents, of the power-factor, of the torque, slip, and output of an induction motor as the load is varied. The fundamental principle upon which the diagram is constructed is that the vector denoting the stator current rotates about a fixed point as the conditions of working are changed, and also that the locus of the free end of this vector is a semicircle. A complete diagram constructed from the data given is shown in Fig. 1; the method of construction is as follows :—

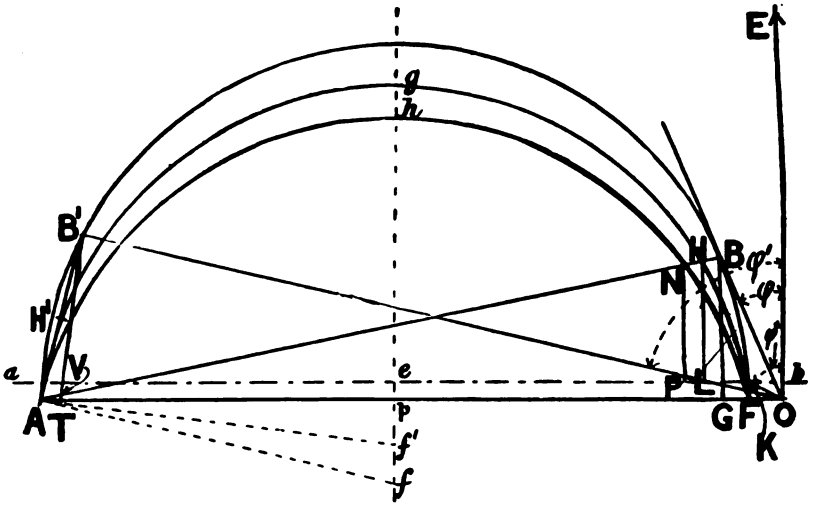

FIG. 1.—CIRCLE DIAGRAM FOR INDUCTION MOTOR.

Since the stator winding is star-connected and the terminal pressure is 380 volts, the phase voltage is

$$E = \frac{1}{\sqrt{3}} \times 380 = \frac{1{\cdot}732 \times 380}{3}$$
$$= 220 \text{ volts (approximately).}$$

The no-load current C_o is 16 amperes, and the power absorbed is 1,550 watts, therefore

$$1550 = E\ C_o \cos \phi''$$
$$= 220 \times 16 \times \cos \phi''$$
$$\therefore \cos \phi'' = \frac{1550}{220 \times 16} = 0{\cdot}44$$
$$\therefore \phi'' = 63° 34'.$$

And since the power-factor of the short-circuit current is 0·23,

$$\cos \phi' = 0{\cdot}23,$$

and

$$\phi' = 76° 43'.$$

Before constructing the diagram, the scale for the currents must be decided upon, and Fig. 1 has been constructed by taking one centimeter for 20 amperes. The diagram is commenced by introducing the two lines OE and OA at right angles to one another, the point O being taken as the point of origin. From O the two lines OK and OB', equal to 0·8 cm. and 15·5 cms. are introduced, making with OE angles of 63° 54' and 76° 42' respectively; these lines respectively represent $C_o = 16$ amperes and $C_o' = 310$ amperes (the standstill current). The lines OK and OB' give the phase of the no-load current and standstill current relatively to the phase-pressure OE. The semicircle AB'F, passing through the points K and B' has its centre at the point p in OA. The dotted line $a\,h$ is drawn through the point K parallel to the line OA. The semicircle FB'A is the locus of the point B', the extremity of the current vector OB'.

The circle for the output, A h F, is drawn from the centre f in the perpendicular to AO through the point p, and the radius A f is perpendicular to AB', since the vector AB' is a tangent to the semicircle A h F, for the standstill current of 310 amperes.

The circle for the torque is obtained as follows : OA and B'A are vectors, the former of which denotes the phase-pressure of 220 volts, whilst B'A represents the sum of the drops in volts due to the stator and rotor resistances. Now OA = 15·95 cms. and B'A = 3·65 cms., and since OA denotes 220 volts, the pressure represented by B'A is

$$\frac{3{\cdot}65}{15{\cdot}95} \times 220 = 50{\cdot}3 \text{ volts.}$$

But the copper drop per phase of the stator winding for 310 amperes (C_o')

$$= C_o' R_a = 310 \times {\cdot}078 = 24{\cdot}18 \text{ volts,}$$

since the resistance of one phase of the stator winding is $\frac{0{\cdot}156}{2} = 0{\cdot}078$ ohm. Therefore,

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B'H', cut off from B'A, is the vector denoting 24·18 volts, and its length is

$$B'H' = \frac{24 \cdot 18}{50 \cdot 3} \times 3 \cdot 65 = 1 \cdot 75 \text{ cms.}$$

The torque circle passes through the fixed points A, H', and F, and its centre is f_1 on $\not p f$, which is readily found by geometry.

The slip line is also easily obtained by dropping a perpendicular B'T from B on to the radius Af_1, and B'T, which is 3·7 cms. in length, denotes 100 per cent. of slip, since the point B' corresponds to the motor being short-circuited and at rest.

We are now in a position to calibrate the diagram, and this is done as follows. The line OB is introduced as a tangent to the semicircle AB'F, a vector for the stator current when the power factor, Cos ϕ, is a maximum, is obtained, and in our case OB = 3·3 cms. It thus represents a stator current of 66 amperes, and its power component is BG equal to 60 amperes, since BG is 3 cms. in length. Consequently the actual input corresponding to a stator current of 66 amperes is

$$\text{input} = 3 \times 60 \times 220 = 39{,}600 \text{ watts.}$$

The total losses are :—

(1) The no load losses are 1550 watts per phase, or $3 \times 1550 = 4650$ watts for the total no load loss.

(2) The copper losses due to the stator and rotor windings.

(*a*) The total stator copper loss is $3C^2R_s$, which is denoted by the vector BH, which is ·35 cm. long.

$$\therefore 3C^2R_s = 3 \times 66^2 \times 0 \cdot 078 = 1019 \cdot 3 \text{ watts.}$$

(*b*) The total rotor copper loss is $3C_r^2R_r$, and is denoted by the vector HN, which is 0·4 cm. long,

$$\therefore 3C_r^2R_r = \frac{0 \cdot 4}{0 \cdot 35} \times 1019 \cdot 3 = 1165 \text{ watts.}$$

The sum of these losses gives the total losses of the motor, neglecting the mechanical friction losses, and this sum is $(4650 + 1019 \cdot 3 + 1165) = 6835$ watts. This gives the output corresponding to the torque exerted by the rotor, for a stator current of 66 amperes per phase, as $39{,}600 - 6835$ or 32,765 watts = 44 h.p. approximately. The b.h.p. will therefore be 44 h.p. less the losses due to mechanical friction ; and as no particulars of these are given, we shall assume the b.h.p. for 66 amperes to be 40 h.p. In the figure, NP represents 44 h.p., and this gives the scale value for any other output, which fixes the point B and the position of the OB denoting the stator current. On the assumption that the frictional losses are 4 h.p., the stator current OB is 66 amperes. The power factor is given by taking the cosine of the angle BOE, which is 24°, and cos 24° is 0·9135. The percentage slip under these working conditions is given by the length VT cut off from B'T by the line AB, which is found to be 0·2 cms., and since B'T or 3·7 cms. denotes 100 per cent., the percentage slip is 5·4 per cent.

SHEAR LEGS.—Are there any simple rules for determining the main dimensions for a set of four folding tubular shear legs to fulfil the following conditions :—

1. To stand 15 feet high when the feet are set on a circle of 3·5 feet radius.

2. To safely sustain a load of 4 tons.

3. The load to be lifted by means of a differential pulley block.

4. The tops of the legs are to be connected by a mild steel pin which passes through the eyes of all four and also through the sling hook.

5. The legs are to be of ordinary welded wrought iron steam pipe ¼-inch thick ; and are not to be braced in any way.

If we may assume that the load is such as may require to be drawn to one side after a vertical lift, it is possible that nearly all the load will be supported by one leg.

We can therefore safely assume that the *whole* load may come upon one leg.

Since the legs are 15 feet high, when standing on a circle of 3·5 feet radius, the true length of each leg will be

$$\sqrt{(15)^2 + (3 \cdot 5)^2} = 15 \cdot 4 \text{ feet.}$$

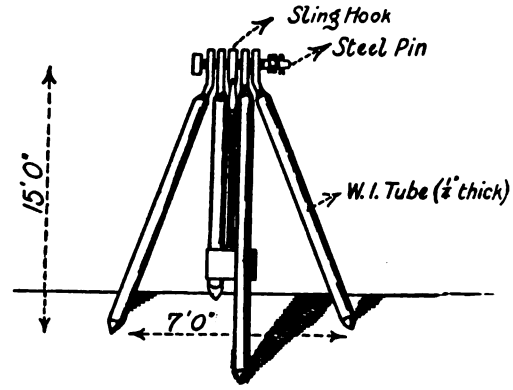

FIG. 1.—SHEAR LEGS.

If we draw a triangle to any scale whatsoever, with a perpendicular to represent 15 feet and a base of 3·5 feet and consequently an hypoteneuse of 15·4 feet, it will serve to represent the slope of the legs and will also serve as a triangle of forces.

If the load of 4 tons be dragged sideways, so that the chain sustaining the load lies practically parallel to the shear leg which we are supposing to take the whole load, the compression can be found by proportion. On referring to the triangle

$$\frac{15 \text{ feet}}{15 \cdot 4 \text{ feet}} = \frac{4 \text{ tons}}{x \text{ tons}}$$

$$\therefore x = \frac{15 \cdot 4}{15 \cdot 0} \times 4$$

$$= 4 \cdot 1 \text{ tons.}$$

Now as the whole load cannot really fall entirely on one leg, the true load will be somewhat less than 4·1 tons. Let us take it at 4 tons.

This is our original figure. We are thus led logically to the simple working rule of designing

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each leg as a strut capable of safely bearing a longitudinal pressure equal to the total load to be carried. For example, a set of shear legs to carry 5 tons should have each leg designed as a strut to carry 5 tons.

Since each leg will be acting as a strut with hinged or rounded ends, the load per square inch will require to be considerably less than the safe compressive stress on a cube or short length of the given material. This strut can only be designed by a method of trial and error.

Take Gordon's formulæ for a wrought iron strut with rounded ends, *i.e.*,

$$\text{Crippling load} = \frac{16 \text{ tons} \times \text{area of strut}}{\left[1 + \frac{4}{2000}\left(\frac{\text{length}}{\text{diameter}}\right)^2\right]}$$

$$\text{Working load} = \frac{\text{Crippling load}}{\text{Factor of safety}}$$

$$\text{Factor of safety} = 4 + \left(\frac{\text{length}}{\text{diameter}} \cdot \frac{1}{20}\right)$$

[Shaler Smith.]

If we try 6-inch diameter we shall find that the working load will be about 4½ tons. This will be satisfactory.

To find the diameter of the pin, assume that the two intermediate legs carry the load, and the other legs serve chiefly for steadiment. This assumption does not at all represent the true conditions, but gives stresses not less than the actual. The mechanical and structural conditions may necessitate the centres of the intermediate eyes being placed about 6 inches apart.

Treating the pin as a beam with a central load, the bending moment will be

$$\frac{W\,l}{4} = \frac{4 \text{ tons} \times 6 \text{ ins.}}{4} = 6 \text{ ton-ins.}$$

The moment of resistance to bending = M R = section modulus × maximum safe bending stress.

The section modulus of a round bar of diameter D = $\frac{D^3}{10}$ approximately.

Take the maximum safe working stress at 7 tons per square inch. Assuming a trial diameter of 2 inches, the M R

$$= \frac{2 \times 2 \times 2}{10} \times 7 = 5{\cdot}6 \text{ ton-ins.}$$

As the pin may bear on the inner edges of the eyes, the effective span may be less than 6 inches, so that a 2-inch diameter pin will be sufficient.

If the pin is strong enough to resist bending it will be quite strong enough to resist the shearing forces. The refinements of these problems are endless, and the above methods are only to be adopted for shears worked by hand; for the larger sizes worked by mechanical power there are many much more intricate conditions involved; and they would require several chapters for their full treatment. The question of bending moments on the pin could scarcely be dealt with satisfactorily in less than half-a-dozen pages. The pin diameter here given may appear excessive, but with folding shears the pin is subject to much ill-usage in setting up and taking down the shears. There is an unfortunate tendency to design these hinge pins as though they were merely to resist double shear under ideal conditions.

STRUT.—A rod of steel, 4 inches in diameter, 10 feet long, acts as a strut, but the resultant load does not act exactly at the centre of each end. The inexactness of loading is (say) h: imagine it to be the same at both ends. If the greatest stress in the material is not to exceed 20,000 lbs. per square inch, and if Young's modulus is 3×10^7 lbs. per square inch, find the greatest load for the strut in three cases: (1) when $h = 0{\cdot}1$ inch; (2) when $h = 0{\cdot}01$ inch; and (3) when $h = 0$.—*Board of Education, Applied Mechanics, Honours*, 1904.

An answer to this question, in which the bending of the beam was assumed to be inappreciable, was given in the June number of TECHNICS (Vol. I., No. 6, p. 617). A good summary of the various recognised methods of dealing with the problem when bending is taken into account, can be found in *Strength and Elasticity of Structural Members*, by R. J. Woods (Edward Arnold: London, 1903). None of the methods given, however, afford an answer to the present problem; the following investigation may, therefore, prove of interest.

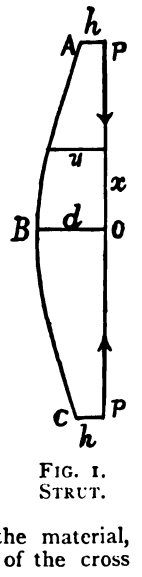

FIG. 1. STRUT.

Let l be the length of the unbent strut, and let P be the load, applied at a distance h from the neutral axis, at either end of the strut (Fig. 1). Let ABC represent the neutral axis of the strut; and let the load line PP be chosen as the axis of x, the mid-point O of PP being origin, and OB the axis of y. The differential equation to the curve into which the strut is bent will be (see *Strength and Elasticity of Structural Members*, p. 230):—

$$E\,I\,\frac{d^2y}{dx^2} = -\,Py \quad . \quad . \quad . \quad (1)$$

where E is Young's modulus of the material, and I is the moment of inertia of the cross section of the strut.

Equation (1) is derived from the consideration that the curvature of the neutral axis at any point is proportional to the bending moment at that point, and the latter is proportional to y, the distance of the point from the line of action PP of the applied forces. Now it is well known that the curvature at any point on the curve

$$y = d \cos \frac{\pi x}{L} \quad . \quad . \quad . \quad . \quad (2)$$

is proportional to y if d is small; so that we may assume (2) to be the equation to the neutral axis of the strut. The cosine curve is chosen in preference to a sine curve, since y must obviously have the same value for numerically equal positive and negative values of x. L is a constant to be determined; it cannot be equal to l unless the strut is centrally loaded, for only in the latter case will the neutral axis cut the line PP at $x = \pm\, l/2$.

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Substituting from (2) in (1), we obtain, after simplifying

$$\frac{E\,I\,\pi^2}{L^2} = P \quad . \quad . \quad . \quad . \quad (3)$$

When the strut is centrally loaded, and $L = l$, (3) gives Euler's well-known formula for the "crippling load"; *i.e.*, the least load which will cause the strut to bend. It is easily seen that, when P is less than the value given by (3), and L has a constant value $= l$, equation (1) can only be satisfied by (2) when $d = 0$.

In the case of the excentrically loaded strut, substituting $x = l/2$ and $y = h$ in (2) gives us the equation

$$h = d \cos \frac{\pi l}{2L} \quad . \quad . \quad . \quad . \quad (4)$$

Let f be the greatest stress produced in the fibres of the middle section of the beam. Then if b is the radius of the section of the strut,

$$P d = \frac{f I}{b} \therefore f = \frac{P b d}{I}$$

If a is the sectional area of the strut, the uniform compressive stress due to the load P is equal to P/a. Hence, if F is the greatest compressive stress which the fibres can withstand without overpassing the elastic limit,

$$F = \frac{P}{a} + f = P\left(\frac{1}{a} + \frac{bd}{I}\right);$$

$$\therefore P = \frac{F\,I\,a}{I + a\,b\,d}. \quad . \quad . \quad . \quad (5)$$

Substituting in (3), and simplifying, we obtain

$$\frac{E\,\pi^2}{F\,a} = \frac{L^2}{I + a\,b\,d} \quad . \quad . \quad . \quad (6)$$

Equation (6), together with (3)

$$h = d \cos \frac{\pi l}{2L} \quad . \quad . \quad . \quad (3)$$

form two simultaneous equations in the unknown quantities d and L. When d has been calculated from these, the maximum permissible load can be found by substituting in (5).

The simultaneous equations (6) and (3) can best be solved graphically. The curves corresponding to (6) and (3) are plotted, and the coordinates of their point of intersection give the required values of L and d. The curve AB, Fig. 2, is the graph of the equation

$$1{,}177 = \frac{L^2}{12{\cdot}56 + 25{\cdot}12d}$$

In plotting this curve, various values of L greater than $l = 120$ were assumed, and the corresponding values of d were calculated. The other two curves in Fig. 2 are graphs of the equation

$$d = \frac{h}{\cos \frac{\pi l}{2L}}$$

where $l = 120$, and h has the values 0·1 and 0·01 respectively. The curve for $h = 0{\cdot}1$ cuts AB at a point corresponding to $d = 0{\cdot}295$. Substituting this value of d in (5), we obtain $P = 1{\cdot}58 + 10^5$ lbs.

The curve for $h = 0{\cdot}01$ intersects the curve AB at a point corresponding to $d = 0{\cdot}085$. Substituting in (5), we obtain $P = 2{\cdot}14 + 10^5$.

When the loading is central, ($h = 0$), we must substitute $L = l = 120$ in (3). This gives us P = 258,000 for the "crippling load" (Euler's formula), *i.e.*, the least load which will produce bending. The maximum load which can be sustained without crushing is, however, $F\,a = 2 \times 10^4 \times 12{\cdot}56 = 251{,}200$ lbs. Thus when the strut is loaded centrally, it breaks from crushing, without bending, when the load is equal to 251,200 lbs.

Thus when $h = 0$, P = 251,200 lbs.
$h = 0{\cdot}01$, P = 214,000 „
$h = 0{\cdot}1$, P = 158,000 „

As Euler's equation for the crippling load is sometimes misunderstood, a short explanation may be useful. If the central load is less than that calculated from (3) ($L = l$), the strut will not bend, though it may fail from crushing. What happens when the load is equal to that given by (3)? The left-hand side of (1) represents the resisting moment at a section (x, y) of the strut: the right-hand side represents the turning moment at the same section. The equation to the neutral axis is given by (2); substituting in (1), we obtain

$$\frac{E\,I\,\pi^2}{L^2}\,d \cos \frac{\pi x}{L} = P\,d \cos \frac{\pi x}{L} \quad . \quad . \quad (7)$$

When the loading is central, L has the constant value l; and since both sides of (7) are proportional to d, it follows that, if bending increases, the moment producing bending increases at the same rate as the moment, due to strain in the fibres, which opposes bending; consequently the load given by (3) which can just cause bending to commence, is sufficient to bend the rod to any extent.

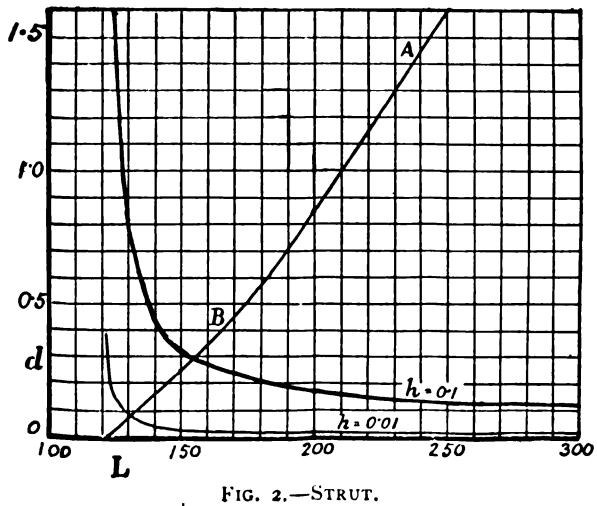

FIG. 2.—STRUT.

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When the fibres are strained beyond their elastic limit, the resisting moment increases more slowly than the bending moment as the deflection increases, and the strut accordingly breaks. Hence we see that when the load attains the value given by (3), the strut becomes *unstable*, whatever may be its strength under crushing or tension.

When the strut is excentrically loaded, equation (4) shows that L must diminish as d increases, so that the left-hand side of (7) increases at a greater rate than the right-hand side, and stability is secured unless the strains in the fibres exceed the limits of elasticity.

MOTOR CAR.—A motor-car moves in a horizontal circle of 300 ft. radius. The track slopes sideways an angle of 10° with the horizontal plane. A plumb line on the car makes an angle of 12° with what would be a vertical line on the car if it were at rest on a horizontal plane: what is the speed of the car? If the car is just not side-slipping, what is the coefficient of friction?—*Board of Education, Applied Mechanics, Stage* 3, 1904.

Let v be the velocity of the car, in ft. per second, while the mass of the car is M lbs. Let G (Fig. 1) be the centre of gravity of the car, which is describing a circle about a point to the

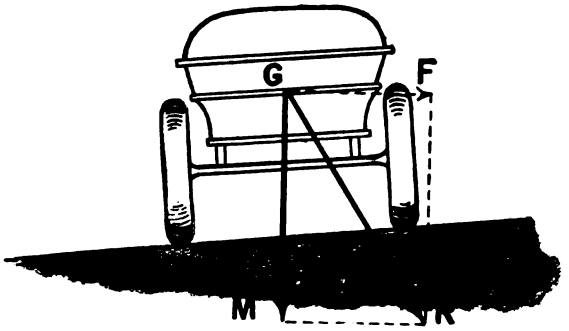

FIG. 1.—MOTOR CAR.

left of the diagram. Then the forces acting at G are as follows:—

1. The weight of the car (M lbs.) acting vertically downwards.

2. The centrifugal force (F), equal to $(Mv^2)/(rg)$ lbs. acting in a horizontal direction from left to right; where r is the radius of curvature of the car's motion, and g is the acceleration due to gravity (32 ft./sec.^{2}).

Draw GM and GF to represent these forces to scale. Then the resultant force will be found by completing the parallelogram GFRM, and drawing the diagonal GR. The line GR represents the direction and magnitude of the resultant force. To find the inclination θ of GR to the vertical line GM, we have

$$\tan\theta = \tan \mathrm{RGM} = \mathrm{MR}/\mathrm{GM} = \mathrm{F}/\mathrm{M}$$
$$= \frac{Mv^2}{rg} \div M = \frac{v^2}{rg} \quad . \quad . \quad . \quad . \quad (1)$$

Since M, the mass of the moving body, does not occur in this expression, it follows that the resultant force acting on the plumb bob will be parallel to the resultant force acting on the car, the inclination of this force to the vertical being given by (1). Then

$$v^2 = rg \tan\theta.$$

In the problem, the plumb line makes an angle of $10° + 12° = 22°$ with the vertical; therefore

$$\therefore\ v = \sqrt{300 \times 32 \times \tan 22} = \sqrt{300 \times 32 \times 0{\cdot}375}$$

= 60 ft. per sec. (nearly) = 40·9 miles per hour.

The resultant force R, acting on the car, makes an angle of 12° with the normal to the track; resolving the resultant force (1) parallel to surface of track, and (2) normal to the track, we have

Component parallel to surface of track
$= \mathrm{R} \sin 12°.$

Component normal to surface of track
$= \mathrm{R} \cos 12°.$

$\therefore$ Coefficient of friction, μ

$= (\mathrm{R} \sin 12°)/(\mathrm{R} \cos 12°) = \tan 12° = 0{\cdot}208.$

TRAIN.—When a train is rounding a curve, is the strain greater on the outer than on the inner rail, or *vice versâ*?

From answers to *Inquirer*, it will be seen that the resultant force acting on each carriage of the train is inclined to the vertical at an angle of which the tangent is equal to $v^2/(rg)$. Let us first suppose that the two rails lie in the same horizontal plane. Then a carriage will exert a vertical force of M lbs. on each rail, combined with a horizontal force (centrifugal) acting away from the centre of curvature, equal to $(Mv^2)/rg$. Owing to the form of the wheels, this horizontal force can only be borne by the outer rail, which therefore bears the greater stress. It is easily seen that the horizontal stress borne by the outer rail will tend to make the carriage leave the rails: to overcome this tendency, the outer rail is generally raised somewhat above the inner rail, so that a transverse straight line drawn through the two rails is inclined to the horizontal at an angle of which the tangent is equal to v^2/rg; in this case the resultant force is normal to the track, and both rails are subjected to equal stresses.

TRACTION.—Calculate the horse-power required to drive a motor car, weighing one ton, up an incline of 1 in 14 at 24 miles per hour, supposing it can reach, but not exceed, the same velocity when running freely down the incline.—*Tutorial Dynamics, by Briggs and Bryan*, p. 243.

The motor car is rising at the rate of (1/14) × 24 miles per hour; therefore, the power required, in ft.-lbs. per minute, in order merely to overcome the pull of gravity, is equal to

$$2240 \times \frac{24 \times 1760 \times 3}{14 \times 60} = 338{,}000 \text{ ft.-lbs. per min.}$$

The motor car, when running freely down the incline, attains the same velocity as that with which it is to be driven up the incline. When the car is running down the incline at a constant velocity, the frictional resistance offered to its motion must be just equal to the component

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of the pull of gravity resolved parallel to the surface; if this were not so, and a resultant force acted on the car, its velocity would either increase or diminish. Let θ be the inclination of the road to the horizontal; then the component of gravity, acting parallel to the road, will be equal to $2240 \times \sin \theta$ lbs. Also, $\sin \theta = 1/\sqrt{1+(14)^2} = 1/\sqrt{197} = 1/14$ nearly. Thus frictional resisting force = 2240/14 lbs. This force is overcome through a distance of 24 miles per hour, or $(24 \times 1760 \times 3)/60$ ft. per minute. Therefore, power required to overcome resistance—

$$2240 \times \frac{24 \times 1760 \times 3}{14 \times 60} = 338{,}000 \text{ ft.-lbs. per min.}$$

$\therefore$ Total power required = 676,000 ft.-lbs. per min.
= 20·5 h.p. nearly.

HYDRAULICS.—A hydraulic lift with ram, load, etc., weighs 10 tons, the ram is 9 inches in diameter, and the friction in the mechanism is equal to 0·05 of the gross load. The accumulator is half-a-mile away, and is loaded to 800 lbs. per square inch: the diameter of the supply pipe is 3 inches. Estimate the speed of ascent of the lift, if the loss of head in the pipe is $0{\cdot}0005\, lv^2/d$: l being the length in feet, d the diameter in feet, v the velocity of water in the pipe, in feet per second.—*Board of Education, Applied Mechanics, Stage* 3, 1904.

Let V be the speed of the lift, in ft. per second; then since the diameter of the supply pipe is $\frac{1}{3}$ the diameter of the ram, it is plain that the speed of water in the supply pipe will be equal to 9V.

Assuming that the "loss of head" is measured in feet of water, the loss of pressure, in lbs. per square inch, will be equal to

$$0{\cdot}432 \times \frac{0{\cdot}0005 \times 2640 \times (9V)^2}{0{\cdot}25} = 184\ V^2$$

Thus the pressure on the ram will be equal to
$(800 - 184\ V^2)$ lbs. per square inch.
Then, equating the work done per second by the water on the ram to the work per second required to raise the lift, etc., we have

$$(800 - 184\ V^2) \times \frac{\pi \times 9^2}{4} \times V = 10 \times 2240 \times 1{\cdot}05 \times V$$

$$\therefore V^2 = \frac{800}{184} - \frac{10 \times 2240 \times 1{\cdot}05 \times 4}{\pi \times 9^2 \times 184}$$

$$= 4{\cdot}35 - 2{\cdot}01$$

$$= 2{\cdot}34;$$

$$\therefore V = 1{\cdot}53 \text{ ft. per second.}$$

SUBMARINE.—A submarine of 300 tons displacement in collision loses 8 per cent. of its buoyancy. Find how much ballast must be got rid of to bring it into same condition as before collision. What would happen if the ballast were not got rid of, and how is this effected? What danger is likely to occur through sudden loss of buoyancy? State what motors are used for propulsion, and how manœuvring power is obtained.

The first part of this question appears to be scarcely practical; for, in the event of a collision of a submarine, resulting in a loss of buoyancy, the commander would scarcely have leisure to calculate how much had been lost, but would speedily lighten the vessel to the fullest possible extent.

Treating the question from a theoretical aspect, it becomes necessary to assume some figure for the "reserve buoyancy" of a submarine. For the sake of argument, let us assume the reserve buoyancy to amount to 50 tons, so that the total weight of the submarine, if brought down to that of the displaced water (a condition commonly termed "floatability nil") would amount to 350 tons.

As the result of an accident, she loses 8 per cent. of the 50 tons, *i.e.*, 4 tons; this leaves the reserve buoyancy as 46 tons, and the displacement of the submarine is 304 tons. (Distinguish carefully between the meanings of "total weight," which includes reserve buoyancy, and "displacement," in which reserve buoyancy is deducted.) If, therefore, 4 tons of ballast be dropped, the vessel will at once regain her original condition; though her stability may possibly have suffered.

What would happen in the case of an accident such as described, depends very much on the type of submarine; a breach in a British or American vessel would entail a repetition of the A1 disaster. The five French submersibles of *Naval* class, and the more recent *Emeraude* class of 422 tons, could lose a large amount of buoyancy without serious damage. The danger resulting from a sudden loss of buoyancy depends, again, on the amount lost, and the celerity with which the loss is counteracted by the action of the crew.

Ballast is got rid of in many ways, differing for vessels of different design. In English and American vessels, the tanks are emptied by the pressure of compressed air; in Continental vessels, detachable safety weights are also carried; and the release of a ton or two from the keel of a vessel, though liable to impair her stability, would, nevertheless, cause her to rise like a bubble to the surface.

Perhaps a hundred different types of motors are used for propulsion. Speaking generally, an oil motor is used for surface work, and an electric convertible motor for "submerged" runs. A convertible electric motor is one run from storage cells, charged by means of a dynamo driven by an oil engine. In certain French submersibles a chemically-heated steam engine is employed on the surface; in the *Glauco* building at Venice, a petrol engine is utilised for both surface and submerged propulsion. The American vessels, and the first five British vessels, use "Otto" gasoline engines. The series A1—A4 use a 16-cylinder Vickers patent oil engine: the Russian *Bubnoff* has a 150 h.p. Daimler, and the German *Howaldt* is run by a Mercedes.

LAUNCHING VESSEL.—Suppose a box-shaped vessel, length 100 feet, breadth 20 feet, depth 10 feet, to be 200 tons weight, and to slide on her keel down ways, the after ends of which have water on them to a height of two feet; at what declivity

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will the ways have to be, in order that (1) she shall not tip; (2) she shall just lift about the fore end, when the C.G. of the ship just passes the ends of the ways?

Let x be the declivity (descent per unit length), which, by the nature of the case, is small. Then when the C. G. is over the end of the ways, the length of keel immersed is $\left(50+\frac{2}{x}\right)$ and the depth of stern immersed is $(50x+2)$.

The displacement is, therefore, $\frac{10}{35}\cdot\frac{(50x+2)^2}{x}$ tons.* The distance of the centre of buoyancy from the fore end of ship is

$$100-\tfrac{1}{3}(50+2/x)=\frac{250x-2}{3x}.$$

The moment of buoyancy about fore end is, therefore,

$$\frac{10}{35}\cdot\frac{(50x+2)^2}{x}\cdot\frac{250x-2}{3x}\text{ ton-feet,}$$

and this just equals the moment of weight about fore end, *viz.*: $250\times 50 = 10{,}000$ ton-feet;

$$\therefore (50x+2)^2(250x-2)=\left(\frac{35}{10}\cdot 3\quad 10{,}000\right)x^2=105{,}000\,x^2$$

$$\text{or } x^3-\frac{60}{625}\cdot x^2+\frac{6}{6250}x-\frac{8}{625{,}000}=0.$$

The last 2 terms in this equation are so small as to be negligible, so that we obtain

$$x=\frac{60}{625}=0{\cdot}096$$

say, for the declivity. For our purpose this can be called 0·1 or 1/10.

We have now to see if this will satisfy the first condition, that the ship shall not tip. To do this, take successive positions of ship down the ways, and see if the moment of buoyancy about after end of ways is always greater than the moment of weight.

For a distance y of the stern from the after end of ways the moment of the buoyancy is

$$\frac{2}{105}(y+20)^2(y-10),$$

so that the value of this moment for values of $y = 60, 70, 80, 90, 100$ are respectively

6,100, 9,250, 13,300, 18,400, 24,700.

The moment of weight for the same values of y are respectively

2,000, 4,000, 6,000, 8,000, 10,000.

The vessel thus will not tip.

It would be an unnecessary refinement in answering this question to attempt to obtain an absolutely correct result, and the above solution is considered to be quite satisfactory, and a declivity of 1/10 would satisfy the conditions laid down to a sufficiently close approximation.

* A ton of sea water occupies 35 c. feet.

VECTORS.—Define a vector and a rotor, and prove that if their axes are parallel, the resultant is a screw. Determine the acceleration with which a nut will descend a smooth screw, fixed in a vertical position, in terms of the radius of gyration of the nut and the pitch of the screw.—*London University, Inter. B.Sc. Engineering*, 1903.

A *vector* is a directed quantity, *i.e.*, a distance measured parallel to a given fixed line, in a certain direction or sense.

A *rotor* is a line of constant length, which rotates about an axis perpendicular to the line. Thus to specify a rotor, we must give (1) the length of the rotating line, (2) the speed of rotation, and (3) the axis of rotation.

Let us suppose one end of a vector to be fixed, while a rotor, of which the axis coincides with the vector, is joined to the extremity of the vector. Now imagine the vector to increase at a given rate, the rotor rotating at a proportional rate. Thus we may suppose that as the vector increases in length by 1 inch, the rotor completes one rotation: then it is clear that the combination of vector and rotor are equivalent to a screw of 1 inch pitch.

Let v_1 be the linear velocity of descent of the nut, at a given instant: then if the pitch of the screw is p, the angular velocity of rotation must be $2\pi v_1/p$. Let k be the radius of gyration, and m the mass of the nut. Then the total kinetic energy of the nut is equal to the kinetic energy due to its linear velocity v_1, added to the kinetic energy due to the angular velocity $2\pi v_1/p$,

$$=\tfrac{1}{2}mv_1^2+\tfrac{1}{2}mk^2\left(\frac{2\pi v_1}{p}\right)^2$$

$$=\tfrac{1}{2}mv_1^2\left\{1+\left(\frac{2\pi k}{p}\right)^2\right\}$$

After a short interval of time t, let the velocity of the descent be v_2. Then the kinetic energy will be equal to

$$\tfrac{1}{2}mv_2^2\left\{1+\left(\frac{2\pi k}{p}\right)^2\right\}$$

During this short interval of time, the *average velocity* must have been equal to $(v_1+v_2)/2$, and, therefore, the nut descended a distance $(v_1+v_2)\,t/2$. Equating the work done by gravity to the gain of kinetic energy, we obtain

$$\frac{mg(v_1+v_2)\,t}{2}=\frac{m}{2}\left\{1+\left(\frac{2\pi k}{p}\right)^2\right\}(v_2^2-v_1^2)$$

$$=\frac{m}{2}\left\{1+\left(\frac{2\pi k}{p}\right)^2\right\}(v_2+v_1)(v_2-v_1)$$

Dividing through by (v_1+v_2), m and t, and transposing, we easily obtain

$$\frac{v_2-v_1}{t}=\frac{g}{1+\left(\frac{2\pi k}{p}\right)^2}$$

But since the linear velocity changed from v_1 to v_2 in the very short interval of time t, $(v_2-v_1)/t$ is the required acceleration.

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INSULATION RESISTANCE.—The potential difference between the outers of a three-wire system of mains is V. A voltmeter of resistance R, or an ammeter with series resistance, is used to test the voltage to earth of each outer in succession, and the numerical sum of the two readings so obtained is V_1. Show that if Ω is the insulation resistance of the mains,

$$\Omega = R\,\frac{V - V_1}{V_1}.$$

From this formula show that if an error of p per cent. is made in reading V_1, the corresponding percentage in Ω is

$$\frac{\Omega + R}{\Omega} \times p.$$

—(*London University, B. Sc. Engineering Examination*, 1903.)

This question refers to the method of testing the insulation resistance of mains by taking three voltmeter readings. When the voltmeter of resistance R is connected across the two outer mains of the three-wire system the reading is V; and when the same voltmeter is used to obtain the potentials v_1 and v_2 respectively of the positive and negative mains, the voltmeter is connected across each main in turn and an earth-connected terminal, so that the voltmeter forms a shunt to the insulation resistance to earth of each main in turn. Now, if r_1 and r_2 be the insulation resistance of the positive and negative mains to earth respectively,

$$\frac{1}{\Omega} = \frac{1}{r_1} + \frac{1}{r_2} \text{ or } \Omega = \frac{r_1 r_2}{r_1 + r_2} \quad . \quad . \quad . \quad (1)$$

since insulation resistances to earth are "in parallel" with one another. Then, when the positive main is connected to earth through the voltmeter, the total resistance between the two outer mains is

$$\frac{r_1 R}{r_1 + R} + r_2 = \frac{R(r_1 + r_2) + r_1 r_2}{r_1 + R} \quad . \quad . \quad (2)$$

and if C_1 be the current which passes to earth during this test we have

$$V = C_1\left[\frac{R(r_1 + r_2) + r_1 r_2}{R + r_1}\right] \quad . \quad . \quad (3)$$

$$\text{and } v_1 = C_1 \times \frac{r_1 R}{r_1 + R} \quad . \quad . \quad . \quad . \quad (4)$$

Similarly, when the negative main is earth-connected by means of the voltmeter, the total resistance between the two outer mains is

$$\frac{r_2 R}{r_2 + R} + r_1 = \frac{R(r_1 + r_2) + r_1 r_2}{r_2 + R} \quad . \quad . \quad (5)$$

and with a current C_2 passing to earth we have

$$V = C_2\left[\frac{R(r_1 + r_2) + r_1 r_2}{R + r_2}\right] \quad . \quad . \quad (6)$$

$$v_2 = C_2 \times \frac{r_2 R}{r_2 + R} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

But according to the question $V_1 = v_1 + v_2$, and from (3) and (4),

$$v_1 = \frac{r_1 R V}{R(r_1 + r_2) + r_1 r_2}; \quad v_2 = \frac{r_2 R V}{R(r_1 + r_2) + r_1 r_2}$$

$$\therefore V_1 = VR\left[\frac{r_1 + r_2}{R(r_1 + r_2) + r_1 r_2}\right]$$

$$= \frac{VR}{R + \frac{r_1 r_2}{r_1 + r_2}} = \frac{VR}{R + \Omega} \quad . \quad . \quad . \quad (8)$$

$$\text{therefore } \Omega = \frac{R(V - V_1)}{V_1} \quad . \quad . \quad . \quad . \quad (9)$$

If an error in the reading of either v_1 or v_2, or of both, makes their sum $\frac{100 + p}{100} V_1$ instead of V_1, then the insulation resistance of the mains appears to be Ω^1, such that

$$\Omega^1 = \frac{R\left(V - \frac{100 + p}{100} V_1\right)}{\frac{100 + p}{100} V_1}$$

$$= \frac{R[100(V - V_1) - pV_1]}{(100 + p)V_1} \quad . \quad (10)$$

but from (8) $\frac{(100 + p)}{100} V_1 = \frac{RV}{\Omega^1 + R}$ . . (11)

Therefore

$$\frac{\Omega}{\Omega^1} = \frac{R(V - V_1)}{V_1} \Big/ \frac{R[100(V - V_1) - pV_1]}{(100 + p)V_1} = \frac{(V - V_1)(100 + p)}{100(V - V_1) - pV_1}$$

$$\text{and } \frac{\Omega}{\Omega^1} - 1 = \frac{\Omega - \Omega^1}{\Omega^1}$$

$$= \frac{(V - V_1)(100 + p)}{100(V - V_1) - pV_1} - 1$$

$$= \frac{pV}{100(V - V_1) - pV_1} \quad . \quad . \quad . \quad (12)$$

but $\frac{\Omega - \Omega^1}{\Omega^1} \times 100$ is the percentage error in the insulation resistance of the mains when a percentage error p is made in reading V_1; consequently the percentage error in the insulation resistance is

$$= \frac{pV}{100(V - V_1) - pV} \times 100$$

$$= \frac{100pVR}{(100 + p)V_1\Omega^1} \text{ from } . \quad . \quad . \quad . \quad (10)$$

$$= \frac{pR}{\Omega^1} \times \frac{V}{\frac{(100 + p)}{100} V_1}$$

$$= \frac{pR}{\Omega^1} \times \frac{V}{\frac{RV}{\Omega^1 + R}} \text{ from } . \quad . \quad . \quad . \quad (11)$$

$$= \frac{\Omega^1 + R}{\Omega^1} \times p$$

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TECHNICS CORRESPONDENCE.

RESISTANCE OF METALS AT LOW TEMPERATURES.

To the Editor of TECHNICS.

DEAR SIR,—In your May issue (p. 509) the idea is put forward that a pure "metal becomes a perfect conductor of electricity," at absolute zero (273°C). In the light of Professor Dewar's researches on "Liquid Hydrogen," this is incorrect, as he has shown that further experiment has demonstrated the fallacy of such a notion.

In this connection I cannot do better than quote from Professor Dewar's presidential address before the British Association at Belfast in 1902. In that part of the address dealing with "liquid hydrogen and helium," occurs the following :—

"But supposing all difficulties to be overcome, and the experimenter to be able to reach within a few degrees of the zero (absolute), it is by no means certain that he would find the near approach of the death of matter sometimes pictured. Any forecast of the phenomena that would be seen must be based on the assumption that there is continuity between the processes studied at attainable temperatures and those which take place at still lower ones. Is such an assumption justified? It is true that many changes in properties of substances have been found to vary steadily with the degree of cold to which they are exposed. But it would be rash to take for granted that the changes which have been traced in explored regions continue to the same extent and in the same direction in those which are as yet unexplored. Of such a breakdown, low temperature research has already yielded a direct proof, at least in one case. A series of experiments with pure metals showed that their electrical resistance gradually decreases as they are cooled to lower and lower temperatures, in such ratio that it appeared probable that at the zero of absolute temperature they would have no resistance at all, and would become perfect conductors of electricity. This was the inference that seemed justifiable by observations taken at depths of cold which can be obtained by means of liquid air, and less powerful refrigerants. But with the advent of the more powerful refrigerant liquid hydrogen, it became necessary to revise that conclusion. A discrepancy was first observed when a platinum resistance thermometer was used to ascertain the temperature of that liquid, boiling under atmospheric and reduced pressure. All known liquids, when forced to evaporate quickly by being placed in the exhausted receiver of an air-pump, undergo a reduction in temperature; but when hydrogen was treated in this way it appeared to be an exception. The resistance thermometer showed no reduction as was expected, and it became a question whether it was the hydrogen or the thermometer that was behaving abnormally. Ultimately, by the adoption of other thermometrical appliances, the temperature of the hydrogen was proved to be lowered by exhaustion, as theory indicated. Hence it was the platinum thermometer which had broken down : in other words, *the electrical resistance of the metal employed in its construction was not, at temperatures about minus* 250°C., *decreased by cold in the same proportion as at temperatures about minus* 200°. *This being the case, there is no longer any reason to suppose that at the absolute zero platinum would become a perfect conductor of electricity; and in view of the similarity between the behaviour of platinum and that of other pure metals in respect of temperature and conductivity, the presumption is that the same is true of them also.* At any rate, the knowledge that in the case of at least one property of matter we have succeeded in attaining a depth of cold sufficient to bring about unexpected change in the law expressing the variation of the property with temperature, is sufficient to show the necessity for extreme caution in extending our inferences regarding the properties of matter near the zero of temperature."

The general interest, the intrinsic importance, and the fact that the subject-matter is not generally known, are responsible for the length of the above quotation, whilst I am responsible for the italics.—Yours faithfully,

S. IRWIN CROOKES.

Clay Cross, Chesterfield, April 17, 1904.

THE MODERN MOTOR CAR.

To the Editor of TECHNICS.

DEAR SIR,—It has been pointed out to me that an error was made in describing the Murray Governor, at p. 451 (TECHNICS No. 5). I should be obliged if you would publish the following amended description :—

"The governor shaft is driven from the engine shaft, and the balls connect with a lever B that holds the throttle valve V open against a spring (not shown) on its spindle. When the balls fly out with increased speed, their action on lever B permits the throttle valve to partly close, and thus reduce the supply of air and gas. A wedge W, however, intervenes, which may be adjusted by means of a hand lever L. If this lever be lifted to its highest position the governor action is felt the sooner because the valve has but a short distance to travel before closing ; but if the wedge be pressed right down, the mixture is only throttled at a much higher speed, for the lever B has to travel much further before the valve closes. Thus the governor," etc.

Yours faithfully,

WILFRID J. LINEHAM.

London, June 15, 1904.

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£25 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 73 competitions have been given in the January, February, March, April, May, and June numbers of TECHNICS.

The present number contains particulars of 7 competitions, for which money prizes amounting, in the aggregate, to £25 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£25 IN PRIZES.

General Rules.

Competitors are requested to note the following rules:—

All writing must be on foolscap paper, only one side of which is to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editor reserves the right to withhold the prize.

All competitions must be addressed to the Competition Department, TECHNICS, 12, Burleigh Street, Strand, W.C., and must reach these offices not later than August 11th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

RADIUM.

£3 prize for the best answer.

In what way do you consider that the discoveries relating to Radium and other radio-active substances will prove permanently beneficial to mankind?

STORAGE OF ENERGY.

£3 prize for the best answer.

Describe the accepted methods of storing energy so as to equalise the load in generating stations. Compare these systems with each other and with the system involving the use of electrical storage batteries.

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COTTON SPINNING.

£3 prize for the best answer.

Describe the latest developments in combing machinery, giving detailed sketches.

ARC LIGHTING.

£3 prize for the best answer.

Why is it necessary to provide an arc lamp with a series rheostat? Give a sketch of any arc lamp mechanism with which you are acquainted, and explain clearly the use of each part.

MECHANICAL ENGINEERING.

£3 prize for the best answer.

Give an account of the latest developments in gas-engine valves, with working drawings.

MECHANICS OF THE GYROSCOPE.

£5 for the best set of answers.

1. Prove that the torque required to turn a gyroscope fly-wheel at a given rate about a diameter is directly proportional to the rate at which the fly-wheel revolves about its axle.

2. Show that the rate at which the gyroscope (represented in Fig. 2, page 49), will turn about the pivot *O* is inversely proportional to the rate at which the fly-wheel is revolving about its axle.

3. Prove that the torque required to turn a fly-wheel about a diameter is equal to $I \omega \omega_1$, where I = the moment of inertia of the fly-wheel about a diameter,

ω = angular velocity of fly-wheel about its axle,

and ω_1 = angular velocity with which the fly-wheel turns about a diameter.

(This result may be deduced from the principles explained in Dr. Preston's article, together with an extension of the reasoning used in answer to *Engineer's* query, May TECHNICS, Vol. I., p. 512.)

4. The fly-wheel of a gyroscope weighs 1 lb.: all of its mass may be assumed to be concentrated at the rim, at a distance of 3 inches from the axle. The supporting ring (similar to Fig. 2, page 49) weighs 4 ozs. The centre of gravity of the fly-wheel and supporting ring is at a distance of 4 inches from the pivot *O*. If the fly-wheel revolves on its axle at a speed of 3,000 R.P.M., at what rate will it turn about the pivot *O*?

THEORY OF STRUCTURAL DESIGN.

£5 for the best set of answers.

1. Find the section modulus of a compound girder built up of a 14-inch × 6-inch, 52 lbs. per foot rolled steel joist with a top plate 9 inches × $\frac{1}{2}$ inch, and no bottom plate.

2. Give a brief synopsis, in a series of numbered paragraphs, of the arguments adopted in this issue, in bringing out the abstract character of moments of inertia and section moduli. Your answer must not exceed 500 words.

3. Design a column section and column base, including gussets and angles, etc., and foundation block all complete for a steel pillar or column to carry 400 tons, assuming that the column may be loaded up to 4 tons per square inch of cross-sectional area. The foundation is to be of medium quality sandstone; the other factors are left to your own judgment.

4. Which column formulæ do you prefer to use? and state your reasons for such preference. Only formulæ for built-up mild steel pillars or stanchions need be given.

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PERSONAL ITEMS.

THE attention of students of boot and shoe manufacture in the metropolis may be called to the City and Guilds of London Leather Trade School, Bethnal Green Road, E. This school is quite unique in its methods of teaching, and bears the proud distinction of being the best equipped leather trade school in the country. Very extensive knowledge is required from any man who wishes to thoroughly understand the business of boot and shoe manufacture; and the Principal of the Leather Trade School, Mr. F. Y. Golding, has arranged a system of study by means of which the knowledge may be obtained.

DR. F. G. DONNAN, lecturer in chemistry at the Royal College of Science, Dublin, has been elected to the Chair of Physical Chemistry recently founded by Sir John T. Brunner in the University of Liverpool.

DR. T. MARTIN LOWRY has been appointed lecturer in science at the Westminster Training College.

MR. R. BLAIR, Secretary in respect of technical instruction for the Department of Agriculture and Technical Instruction in Ireland, has been appointed executive officer for the performance of duties in connection with the administration of the Education Acts by the London County Council Education Committee.

DR. D. PACINI, of Rome, has described a series of careful experiments made by him with the object of observing the effects which M. Blondlot and other investigators ascribe to N rays. Dr. Pacini was unable to observe any of the effects described by M. Blondlot and his pupils.

THE *Westminster Gazette* of May 27th contains an account of an interview with Lord Kelvin, who is reported to have stated that he considers it unlikely that the source of the energy of radium lies in the element itself. He remarked :—"It seems to me absolutely certain that if emission of heat at the rate of 90 calories per gram per hour found by Curie at ordinary temperatures, or even at the lower rate of 38 found by Dewar and Curie from a specimen of radium at the temperature of liquid oxygen, can go on month after month, energy must somehow be supplied from without."

A PAPER, published by Professor Karl Pearson, on contributions toward a mathematical theory of evolution, bears the following inscription on the title-page :—*Department of Applied Mathematics, University College, University of London—Drapers' Company Research Memoirs.* The Drapers' Company has given a sum of £1,000 to the University of London, for the purpose of furthering research pure and simple; in no way could part of this sum have been better spent than in the publication of Professor Pearson's valuable researches.

WE have received from Messrs. David Bridge and Co., Engineers and Millwrights, Castleton Iron Works, Castleton (late Salford), an illustrated catalogue of Heywood and Bridge's improved patent friction clutches, combining the 1899 patent.

THE JAPANESE PHYSICIST, H. Nagaoka, contributes a paper on the Electron Theory of Spectra to the *Philosophical Magazine* for May, in which an attempt is made to determine the structure of an atom which will vibrate in such a manner as to emit waves in the manner required to account for the line spectra of the elements. He conceives an atom to consist of a central charged mass, surrounded by a ring of equidistant charged particles; the particles repel each other, and are attracted by the central mass, with forces varying according to the inverse square law. He shows that such a system agrees qualitatively with the observed phenomena of the emission spectra of the elements.

MESSRS. WHITTAKER AND CO. announce the publication of a new work by H. M. Hobart, M.I.E.E., entitled, "Electric Motors: their Theory and Construction." This work will deal fully with the design of Continuous-Current and Induction Motors, and will be characterised by considerable departures from conventional methods.

MR. JOHN WILSON, B.Sc., has been appointed to the post of Junior Assistant in the Physics Department of the Merchant Venturers' Technical College, Bristol. Mr. Wilson takes the place of Mr. Margetson, who has been promoted to the post of Assistant Lecturer in the Engineering Department.

ON the occasion of the official celebration of His Majesty's birthday, the King conferred a large number of honours, including a Knighthood on Professor James Dewar, and a Baronetcy on Mr. George White. Professor Dewar's researches on the liquefaction of gases are well known. Mr. George White is one of the pioneers of electric street traction.

THE only English motor cars which were in at the finish of the Gordon Bennett race were the two Wolseley cars ridden by Girling and Jarrott. Girling was fourth in the first round, third in the second, seventh in the third, and ninth in the fourth; he obtained the ninth place at the finish. Jarrott was fifth in the first round, fifth in the second, ninth in the third, and tenth in the last, and tied with the Italian, Cagno, for the tenth place. The type of car ridden by Jarrott is represented on the right of Fig. 1 (p. 4). The middle car in the same figure is of the type ridden by Girling.

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RESULTS OF APRIL COMPETITIONS.

GENERAL COMPETITIONS.

No. 1.—**For the best and second-best home-work book, or set of books, in each of the three following subjects :—**

(*a*) **Physics ;**
(*b*) **Engineering (Mechanical or Civil) ;**
(*c*) **Electrical Engineering.**

(*a*) FIRST PRIZE, £3.—J. H. Drape, 18, Ackroyd Avenue, Gorton, Manchester (Gorton Technical School).

SECOND PRIZE, £2.—Thomas J. Sack, 487, Caledonian Road, Holloway, N. (City and Guilds Technical College, Finsbury, E.C.).

SPECIAL HONOURABLE MENTION :—A. D. Holdcroft (Sutherland Technical Institute and Longton High School); Russell D. Warren (Laurence High School, Macclesfield).

(*b*) FIRST PRIZE, £3.—John Stansfeld, 5, Hawthorn Street, Holbeck, Leeds (The Leeds Institute of Science, Art and Literature).

SECOND PRIZE, £2.—Archibald Reid, 2, Eastfield Terrace, Dumbarton (Glasgow and West of Scotland Technical College).

SPECIAL HONOURABLE MENTION :—J. G. Wallas (Battersea Polytechnic) ; J. H. Drape ; T. J. Sack ; Walter Snell.

(*c*) FIRST PRIZE, £3.—G. S. Dearling, 35, New Street, St. John's Wood, N.W. (City and Guilds Technical College, Finsbury, E.C.).

SECOND PRIZE, £2.—R. E. C. Ihlee, 22, Parkfield Road, New Moston, Manchester (Manchester Municipal School of Technology).

SPECIAL HONOURABLE MENTION :—J. Lewis (G. E. Railway Mechanics' Institution) ; T. J. Sack.

No. 2.—**Explain the hydro-dynamical law, "Where the velocity is greatest, the pressure is least." Give instances of striking phenomena and mechanical appliances which depend on the truth of this law.**

PRIZE, £3.—M. W. Brayshay, 1, Rochester Avenue, Rochester.

SPECIAL HONOURABLE MENTION :—Gordon Stewart ; Henry J. Jones.

HONOURABLE MENTION :—George Lees.

No. 3.—**State what you know of Mercerisation.**

PRIZE, £3.—B. J. Eaton, 37, Belitha Villas, Barnsbury Park, N.

SPECIAL HONOURABLE MENTION :—Alfred C. Wilkinson ; Fred. C. A. H. Lantsberry ; James H. Smith.

HONOURABLE MENTION :—G. F. Butterworth; Walter W. Marland ; Frederic Buckley.

No. 4.—**Give details of the design of an alternating current transformer of 5 k.w. capacity ; the voltage of supply being 1,000 volts, and the ratio of transformation, 10 : 1.**

PRIZE, £3.—Frank Shaw, 6, May Street, Clayton-on-Mersey, Manchester.

SPECIAL HONOURABLE MENTION :—Jos. W. Beswick.

HONOURABLE MENTION :—A. P. Chalkley.

No. 5.—**Houses built on the London clay are liable to crack, owing to the swelling of the clay when moist, and its shrinkage on drying. Describe how the design of a house should be modified in such circumstances.**

PRIZE, £3.—"Lancastrian." (Will "Lancastrian" please favour us with his address.)

SPECIAL HONOURABLE MENTION :—Harold Slicer ; J. Herbert Belfrage.

HONOURABLE MENTION :—Martin Shaw Briggs ; W. J. Morgan.

No. 6.—**The best essay on "The Duties of a Central Station Electrical Engineer."**

PRIZE, £3.—H. A. Stewart, Sunnyside, York Road, Southend-on-Sea.

SPECIAL HONOURABLE MENTION :—M. J. Tweedie.

HONOURABLE MENTION:—Aubrey L. Telling.

No. 7.—**Special Competitions.**—(See below).

SPECIAL COMPETITIONS.

I.—Questions on Dynamos.

PRIZE, £5.—This prize has been equally divided between two competitors : I. M. Chippendale, Scholes, near Leeds ; William J. Williams, 528, Caledonian Road, N.

II.—Questions on Theory of Structural Design.

PRIZE, £5.—Wilfred Harrod, 300, Petre Street, Sheffield.

SPECIAL HONOURABLE MENTION :—W. J. Morgan ; Samuel Lees.

III.—Questions on Steel.

PRIZE, £5.—F. Rogers, 17, Causeway, Cambridge.

SPECIAL HONOURABLE MENTION:—T. M. Barlow ; Ernest O. Way.

IV.—Questions on Petrol Motors and Motor Cars.

PRIZE, £5.—Samuel Lees, 1, Trafalgar Street, Broughton, Manchester.

SPECIAL HONOURABLE MENTION:—H. H. Francis Hyndman ; H. A. Stewart.

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F. W. LANCHESTER.

Photo. by Harold Baker, Ltd.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. II. AUGUST, 1904. No. 8.

PROGRESS OF SCIENCE AND TECHNOLOGY.

SOME months ago it was announced by Heydweiler that a sealed tube containing 5 grams of concentrated radium bromide lost in weight to the extent of no less than 0·02 mg. daily. This conclusion has been rendered very doubtful by the more recent experiments of Dorn. Thirty milligrams of a much more active specimen of radium bromide were enclosed in a tube of alkali-free glass, and counterpoised against a similar tube containing sand. Each tube weighed about a gram, and the difference in weight was less than half a milligram. The weighings were carried out with the utmost care, and the difference was found to be, as the mean of five weighings between December 28th and January 4th,

Loss in Weight of Radium Salts

$$-0{\cdot}3824 \pm 0{\cdot}0013 \text{ mg.};$$

three weighings between March 25th and 28th gave the difference as

$$-0{\cdot}3833 \pm 0{\cdot}0004 \text{ mg.},$$

and eight weighings between March 25th and April 10th gave

$$-0{\cdot}3820 \pm 0{\cdot}0011 \text{ mg.}$$

The "loss" in weight cannot therefore have been greater than 0·001 mg. in three months, whilst Heydweiler's experiments would have indicated a loss of 0·011 mg.; or, making allowance for the increased activity of the material used by Dorn, a loss of 0·1 mg. The loss in weight noted by Heydweiler must therefore be ascribed to some secondary cause.

IN connection with Dorn's experiments, an observation was made which afforded a striking illustration of the intense electrical effects produced by radium salts. The continual electrolysis of water by these salts was noted by Giesel, and their power of ozonising the surrounding air, and producing oxides of nitrogen, is well known. The observations of Sir William and Lady Huggins showed that radium salts are capable, at ordinary temperatures, of exciting the nitrogen of the atmosphere, in such a way as to wring from it the band spectrum which it emits under the intense electrical forces of a vacuum tube, or in certain forms of spark discharge. Sir William Crookes has recently shown that radium salts are capable of blackening the surface of a diamond in much the same way as the kathode rays of a highly exhausted vacuum tube. The graphite produced is exceedingly hard, and its resistance to the action of oxidising agents indicates a temperature of formation of 3,000° C.

Electrical Properties of Radium Salts

DORN'S observations are of importance, as affording a possible explanation of the colouring of glass by radium salts, and of the "explosions" of radium salts that have been recorded from time to time. The tube used for the gravitational experiments, being free from alkali, was not darkened to the same extent as tubes of ordinary glass. The tube, which had been sealed on December 3rd, was opened on May 27th, and for this purpose a triangular file was used. As soon as the file touched the glass, the tube was pierced by an electrical spark which was clearly visible in the bright

Electrolysis of Glass by Radium Salts

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sunlight immediately in front of a window; and the sound of the spark was so loud that an assistant who was in the room at the time mistook it for the discharge of an induction coil, which, however, was not even connected to the battery. In explanation of this observation, it is suggested that the escape of the negatively charged β-rays, combined with the retention of the positively charged α-rays, produced a difference of potential between the inside and outside of the tube, and that at the end of six months this had become so great as to pierce through a thickness of 0·2 mm. of glass. It is well known that soft glass is an electrolyte at temperatures but little above the boiling point of water, and it is probable that the electrical stresses produced by radium salts find relief in electrolysing the glass; but that when hard glass is used, relief can only occur when the stress becomes sufficient to pierce the glass and scatter the contained salt.

The Atomic Weight of Radium

One of the outstanding problems in connection with the chemistry of radium is the discrepancy between the value 225 for the atomic weight as given by Madame Curie, and the value 258, deduced by Runge and Precht from a comparison of the spectrum of radium with those of the homologous elements calcium, strontium, and barium. Some uncertainty exists, however, in the method adopted in deducing the atomic weight of the fourth element of the series. This uncertainty is similar to that which appears in considering a series of numbers such as 1, 2, 4, which may be the first three members of the series 1, 2, 4, 8, 16, 32, or of the series 1, 2, 4, 7, 11, 16. Dr. Marshall Watts has called attention to the fact that a number of simple relationships can be found between the spectrum of radium and those of mercury, barium, and calcium, if the atomic weight be assumed to be 225. Whilst the evidence is too speculative in character to afford a trustworthy method of deducing the atomic weight, it serves at least to show that Madame Curie's value is not necessarily at variance with the spectroscopic evidence.

Electrical Conductivity of Radium Salts

In view of the many extraordinary properties of the radium salts, it would not have been surprising if these salts had shown an exceptional behaviour when used as electrolytes. That this is not the case is shown by the recent observations of Kohlrausch and Henning, who have shown that over the range from N/20 to N/12000 the electrical conductivity of radium bromide is perfectly normal, and closely resembles that of barium bromide. It is of interest to note that the electrical measurements serve to confirm Madame Curie's value for the atomic weight of radium, since the value 258 given by Runge and Precht would place radium in a group with the monovalent metals, instead of with calcium, strontium, and barium.

The Gobron-Brillé Distributer

Judging from actual results, one of the most successful carburetting devices, whether spray, surface, or positive feed, at present employed with oil engines, is that fitted to the Gobron-Brillé motor. It is one of the positive-feed type, and its success is rendered the more conspicuous by the general failure which has attended others of this type. For some time past there has been much animated discussion on the value of alcohol as a fuel for motors; many experiments have been made, chiefly in France, where the most successful trials were accomplished with the Gobron-Brillé engine, the fuel-distributer described below having proved itself quite capable of carburetting the air to give a powerful explosive mixture with this refractory spirit.

We are here chiefly concerned with the distributer as applied to the Cadogan lorry; for it is in this commercial development of the Gobron-Brillé engine that the efficiency and economy of this particular carburettor are seen to their best advantage. The fuel used is benzoline, which can be obtained at a cost of only 7*d*. a gallon. The specific gravity averages about 0·750. Thus it is considerably heavier than petrol, and is more difficult to manipulate in the motor; but it possesses a distinct advantage, since it is very much cheaper than petrol. The difficulties of successfully converting the potential energy of this fuel into mechanical energy have been so persistently attacked, that a Gobron-Brillé motor is now not only able to operate satisfactorily with this quality of spirit when running normally, but it can be started cold, a phenomenon which can be traced as being due in no small measure to the excellence of the distributing device. Fig. 1 is a partly sectional plan view of the carburettor. E is a truncated cone in which pockets D are recessed at equidistant intervals. Each of these pockets is a receptacle for just sufficient benzoline for one explosion. The cone just fits into a box H, in which it can revolve on

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the axle G. To one extremity of this axle is rigidly attached a ratchet wheel K, with as many teeth as there are pockets in the cone. The pawl L is actuated by a rod and eccentric driven from the crank shaft of the motor, through the medium of a governor which regulates the supply of spirit from the distributer. Benzoline is supplied by a gravity feed into the pockets, D, as they pass the feeding orifice F. Provided the engine does not exceed a certain speed, the pawl L engages with a tooth on the ratchet wheel K at each revolution of the crank shaft, and the cone E is driven round until a pocket is exactly opposite the junction of two orifices, one of which establishes communication between the pocket and atomiser C, while the other leads from the pocket to the open air by way of the channel J. During the suction stroke of the engine there will be a diminution of pressure in A. Consequently air will rush in through J to restore equilibrium, carrying with it the charge of benzoline. C is the atomiser—a perforated tube across the induction pipe A, and in communication with the distributer. Extra air is admitted in a regulated quantity through B, and is made to pass the atomiser, with the result that the spirit is further pulverised and forms with the air an explosive mixture which is passed into the cylinders in the usual manner.

The question naturally arises: "Do not the cylinders and valves become excessively dirty and sooty as a consequence of using such heavy fuel?" The answer to this question is emphatically "No!"; for the speed of the engine is governed in such a way that when it exceeds a certain rate, the governor operates in a manner analogous to the familiar "hit and miss" principle so extensively employed in gas engine practice. The supply of fuel is wholly cut off from the engine, and instead of making an impulsive stroke, the pistons make a scavenging stroke by drawing in a charge of fresh air instead of an explosive charge. This result is attained by setting the governor so that, above the critical speed, it disengages the pawl from the ratchet, causing a temporary suspension of the motion of the cone E with its spirit-loaded recesses D. The action of altering the position of the throttle adjusts the tension of the spring controlling the governor, and at the same time varies the area of the main air inlet connected with B, in such a manner that a perfect mixture is drawn into the cylinders. The governor is of the inertia type extensively adopted in gas engine practice, the principle of which is familiar to all who have studied the gas engine.

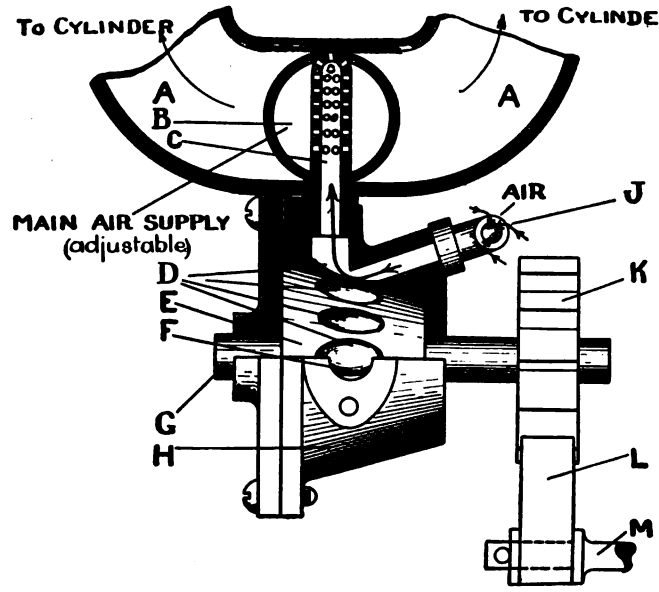

FIG. 1.—THE GOBRON-BRILLÉ DISTRIBUTER.

Tensile Strength of Steel at High Temperatures

A QUESTION of considerable importance is raised in two papers by Bach, that have recently appeared in the *Zeitschrift des Vereines deutscher Ingenieure*. It is there shown that the mechanical properties of steel are very greatly modified by raising the temperature. In the neighbourhood of 200° there is an increase in tensile strength of about 20 per cent. This, however, is accompanied by a very serious reduction in the ductility of the metal; in one case the reduction between 20° and 200° was in the ratio of 1 : 1·4; while in another steel, having very similar properties when cold, the reduction was in the ratio of 1 : 3·2. At higher temperatures the ductility again increases, but the brittleness of the metal reaches a maximum at the average temperature of a modern high-pressure boiler. The tests now recorded have therefore a very important bearing on the design of boilers; and in view of the irregular behaviour of different samples of steel when heated, there

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is much force in the author's contention that boiler-plates should be tested in the neighbourhood of their working temperature as well as at ordinary temperatures.

Industrial Progress and Power Supply

A PROBLEM of considerable importance is touched upon by Mr. Kershaw in the introduction to his article on Electro-metallurgy, appearing in this issue of TECHNICS. Modern civilisation demonstrably depends on the use of machinery and the utilisation of mechanical power to supplement the feeble efforts of man. In attempts to forecast the future of a country, the question of power supply should receive the most careful consideration: for a country destitute of sources of power is cut off from the possibility of engineering development, and must therefore ultimately fall into a position of minor importance. The coalfields of England have heretofore supplied the power on which her commercial prosperity has rested; but with every ton of coal used her resources are diminished; and the question arises, how will the future of Great Britain be affected by the exhaustion of her coalfields? There are numerous minor sources of power which are now scarcely used; but to what extent could these sources be trusted to supply the energy now derived from coal? The energy of the winds might be utilised, but the practical difficulties are disheartening. The chief trouble arises from the extreme variability of the winds, which might leave a factory idle for a week or a month, and then for a short time supply energy at a rate too great to be utilised. From time to time various schemes have been proposed for utilising the energy of the tides; but here again variability of supply diminishes the possible usefulness to such an extent that there appears to be no very attractive prospect in this direction. The power which could be derived from our rivers is small, and is rendered insignificant by its wide distribution. On what source of power, then, can we trust to supply our needs in the future? This is a question which, at present, admits of no satisfactory answer. On the continent, extensive schemes for growing beet-root and other vegetables, for the purpose of ultimately producing alcohol for combustion engines, are now in progress; but it is questionable whether the necessary supply of energy could be obtained from this source. When we burn coal, we use up in an hour the solar energy which the coal-producing plants stored up during years in the by-gone carboniferous period. Considering the earth as a whole, the rate of supply of solar energy is far in excess of our needs; it has been calculated that the power conveyed to the earth by sunlight amounts to about 100,000 h.p. for each inhabitant of the globe. The small fraction of this power which can be recovered from the winds, tides, rivers, and vegetation of the earth would probably be ample for a population far greater than that of the earth at present; but particular countries, such as Great Britain, would get but an insignificant share of the world's power. However this may be, it appears certain that the manufacturing centres of the future will be found close to the largest sources of available power, and these latter, so far as we can judge, will be the great rivers of the earth. Speculations as to the ultimate future of countries like Great Britain are too disquieting to be pursued at length.

The Klinger Boiler Gauge

THE function of a boiler gauge is simple: to clearly show the height of the water within the boiler. At first sight it would appear easy enough to design an appliance which would fulfil this function; but on further consideration a number of difficulties suggest themselves. A boiler gauge of the ordinary tubular form is liable to burst, so that some protective device becomes necessary. But the greatest difficulty lies in designing a gauge which unmistakably indicates the height of the water in it. Water being a transparent substance, there is little difference between the appearance of a tube entirely filled with water and that of one completely empty. Further, if the water surface in a gauge-tube generally occupies a particular position, a solvent action occurs on the glass near the surface of the water; and if the tube is emptied after long use, the etched glass simulates the appearance of the water surface, and might be mistaken for the latter, unless careful examination is made. In the Klinger gauge the above difficulties are overcome by the application of a well-known optical principle. Let a ray, travelling in glass, be incident on a surface separating this medium from air, and let the angle of incidence (*i.e.*, the angle which the ray makes with the normal to the surface) be equal to i. Then the ray refracted into the air will be inclined to the normal to the surface at an angle r, given by the equation

$$\sin r = \mu \sin i,$$

where μ is the refractive index of the glass.

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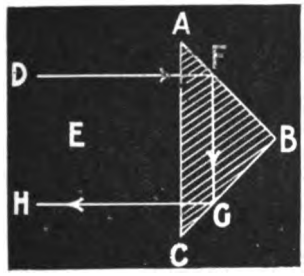

FIG. 2.

Now the largest value which a sine can have is unity, and this value will be attained when the corresponding angle is equal to 90°. Thus when i has a value such that $\mu \sin i$ is equal to unity, the angle r will be equal to 90°, or the refracted ray will emerge parallel to the refracting surface. If $\mu \sin i$ is greater than unity, no refracted ray can be formed; the incident ray then gives rise only to a ray reflected back into the glass, so that no light penetrates the surface. The value of i which makes $\mu \sin i$ equal to unity is termed the *critical angle* of the medium; to determine the critical angle for glass ($\mu = 1{\cdot}5$), we have the equation

$$1{\cdot}5 \sin i = 1;$$

$$\therefore \sin i = 1/1{\cdot}5 = 0{\cdot}666;$$

$$\therefore i = 42° \text{ (nearly).}$$

Consequently, if a ray of light, travelling in glass, falls on a surface separating that medium from air, at an angle of incidence greater than 42°, the ray will be totally reflected, and the surface will present to the eye an appearance resembling polished silver.

Let A B C (Fig. 2) represent the transverse section of a glass prism, the angle at B being equal to 90°, while the angles at A and C are each equal to 45°. Then a ray D F, perpendicular to the face A C, will enter the glass without refraction, and will fall on the face A B at an angle of 45°; it will therefore be totally reflected in the direction F G parallel to A C. As it falls on the surface B C at an angle of 45°, it will be once more totally reflected at G, and will finally leave the face A C in the direction G H normal to A C. It is easily proved that all rays entering the face A C nearly normally will be totally reflected from the surfaces A B and B C; so that to an eye placed near E the surfaces A B, B C will present the appearance of polished silver, and objects to the right of the prism will not be seen.

Let us now suppose that the space to the right of the prism, instead of being occupied by air, is filled with water; then since the refractive indices of glass and water are nearly equal, the ray D F will no longer be totally reflected at F, but will proceed with a slight deviation into the water. In this case, an eye placed near E (Fig. 2) will see the objects in the water to the right of the prism, and the surfaces A B, B C, will no longer present a silvery lustre. In other words, total reflection of the light from the surfaces A B, B C, which gives the surfaces a silvery lustre, depends on the presence behind the prism of a medium with a refractive index much less than that of glass.

FIG. 4.

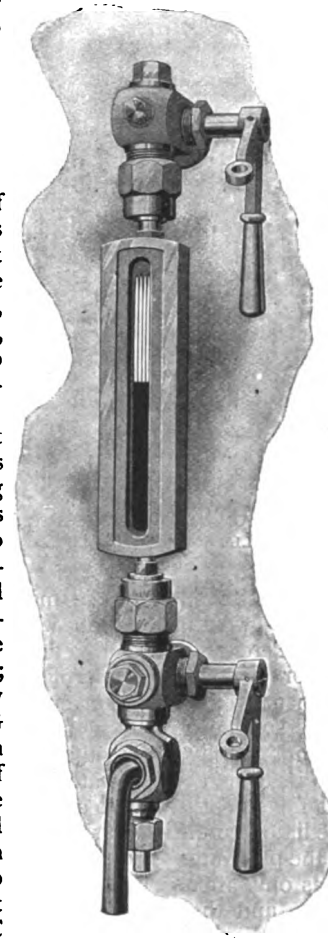

FIG. 3.—THE KLINGER GAUGE.

Returning to the Klinger gauge, this consists of a metal case (Fig. 3), closed on three sides, but provided with a glass window in front. The glass is corrugated on its inner surface (Fig. 4); it will be readily understood that when the gauge is occupied by air or steam, the corrugated glass surface will present a silvery lustre to the eye. The internal surface of the case is blackened; and when part of the gauge is occupied by water, this part will appear dead black (Fig. 3), since in this part the eye sees only the internal blackened surface of the case. There can be no mistake, therefore, as to the height at which the water stands in the gauge; nor can there be any question whether the gauge is entirely filled with water, or is empty. The glass window is about half-an-inch thick, so that there is no fear of its bursting. Before the gauge leaves the works, it is tested at 200 lbs. or 500 lbs. pressure, according

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as it is to be used for low or high pressure boilers.

On Technological Chemistry in New Zealand

A VERY interesting and instructive address on "Recent Advances in Technological Chemistry," was given before the Wellington Branch of the New Zealand Philosophical Society, early in May last, by Professor Easterfield. The professor, who occupies the Science Chair in Victoria University College at Wellington, only recently went out from England to join the staff of the newly-founded college. In opening his lecture, Professor Easterfield said that his subject covered so wide a field that it was not easy to decide where to begin. The manufacture of sulphuric acid, a prime essential in all arts and manufactures, was one of the most interesting examples illustrative of his subject. For a century this valuable solvent had been produced by the cumbrous and costly "lead-chamber" process, which he described in detail. Improved methods were due entirely to investigations and discoveries in the field of pure science. The first discovery bearing on the subject was made early in the nineteenth century by Sir Humphry Davy, who discovered that a platinum wire at comparatively low temperature would cause gases to ignite. In 1831 Peregrine Phillips found that powdered or spongy platinum possessed this quality in a higher degree; and the production of sulphuric acid in the laboratory was so simplified by the application of this fact that its general commercial adoption was looked for seventy years ago as an event of the immediate future. But in practice, on a large scale, the platinum speedily lost its virtue; and it was only after long and exhaustive investigation, and the most delicate experimenting, that a great German house has recently found the cause, and brought the platinum method into commercial use. Sulphuric acid, which can be bought at a penny a pound in England, is for various reasons unobtainable in New Zealand under threepence—a prohibitive price for manufacturers. It was the cost of sulphuric acid which caused the closing down of the promising Orepuki Shale-works (in the South Island of New Zealand) on which £120,000 had been expended. The cheap production of sulphuric acid is, therefore, a matter of great practical importance in this colony. From sulphuric acid the lecturer passed on to the synthetic manufacture of indigo, and the production of alcohol from sawdust; even prohibitionists would admit, he said, that alcohol was indispensable in the arts, whatever objections might be raised to it as a beverage. In no department has the application of modern science been more beneficial than in the white-lead industry. Instead of the three weeks or so required by the old methods, it had become possible to convert litharge into the best white-lead in twenty minutes; and he believed that arrangements were on foot to establish in Wellington white-lead works which were to be conducted on the most advanced methods. In conclusion, whilst fully acknowledging the value of the education given in technical schools, the professor strongly emphasised the inadequacy of such training to meet the higher requirements of modern industries. Accurate scientific grounding (as distinguished from mere technological education), and a habit of close and accurate research, were part of the necessary equipment of all who would excel in the field of manufactures. For the day had long passed when the manufacturer might hope to stumble by accident on a discovery that would revolutionise the methods of his craft.

FIG. 5.—AUTOMOBILE TOWER WAGON FOR TROLLEY WIRE REPAIRS.

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Electric Traction. Motor-Driven Tower Wagons for Overhead Construction Repair

Amongst the troubles of an electric tramway engineer are accidents which occasionally happen to the overhead wires, and stop the traffic on a section of the line, until the necessary repairs can be effected by aid of a tower wagon. To give an idea of the number of calls for the tower wagon, it may be mentioned that on a new line, twelve miles in length, there were thirty calls in eight months. To reduce the interruptions of traffic to a minimum, a rigid inspection of the line is usually made at night-time, when the current is cut off. Nevertheless, accidents to the overhead wires cannot be entirely eliminated; and the time lost in repairs amounts to a considerable item, when the loss in passengers' fares is taken into account. On sections which extend some miles from the place where the tower wagon is stabled, considerable time often elapses before a horse-driven wagon can arrive on the scene of an accident. A great deal of this time would be saved if a motor-driven vehicle were employed; so Messrs. Robert W. Blackwell & Co., whose horse-drawn tower wagons are very well known, have now designed the petrol motor wagon, shown in Fig. 5. Such a wagon must necessarily cost more than one of the ordinary type, but it saves much more than the interest on the outlay and the cost of its maintenance, owing to the rapidity with which it can reach the scene of an accident.

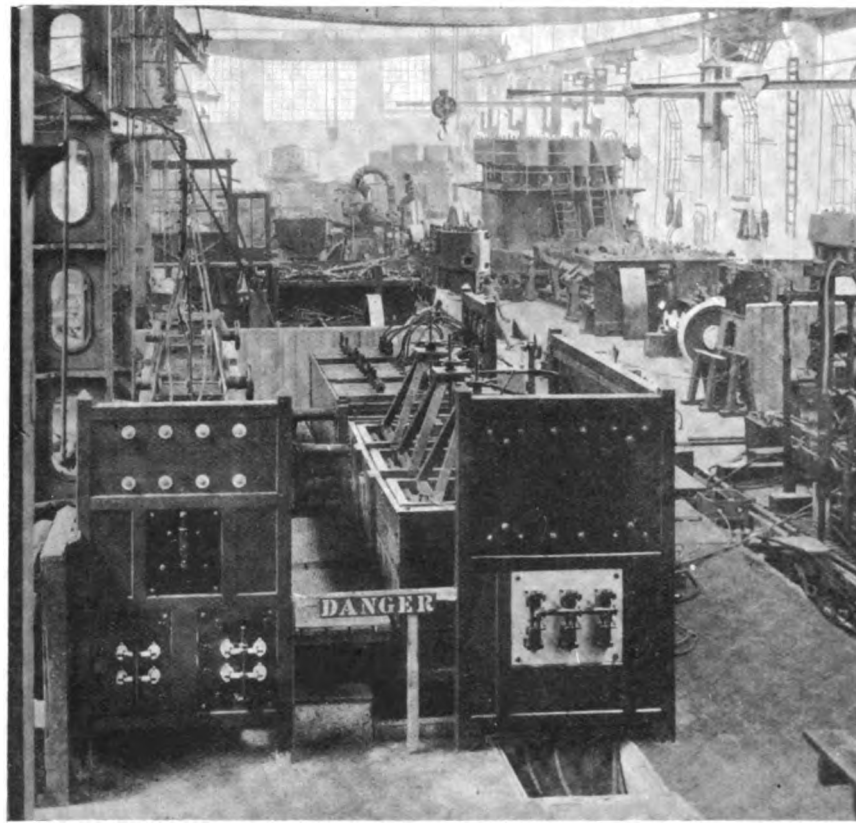

Fig. 6.—Water Resistances in the Test-house of Messrs. Bellis and Morcom.

With more particular reference to the automobile wagon (Fig. 5) recently delivered to the Newport Corporation Tramways, the following details are of interest. The general arrangement of the engine and gearing is similar to that used in modern motor-car practice; the parts are made especially strong so as to withstand rough usage. The engine is a four-cylinder 22-b.h.p. petrol motor, running at a speed of 700 r.p.m. The engine is controlled by a governor of the centrifugal type; the ignition is on the high-tension system, with trembler induction coil, current

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being supplied from a set of accumulators. The gearing is arranged to give four forward speeds, and one reverse. The road wheels, thirty-four inches in diameter, are fitted with solid rubber tyres. The car has a wide gauge, so that it can run over a car pit without danger; it also has a long wheel base, which increases its stability. Brakes are provided on the inside of the chain-wheels, and also on the countershaft.

The lower portion of the tower is stayed so that strains are transmitted directly above the front and rear axles. The tower is of the usual extension type. Angle iron slides are used, and the whole is very strongly constructed. The revolving platform will carry four or five men, and is elevated by two square-threaded screws connected together by bevel gearing; to raise it to its full height takes about a minute and a quarter. The weight of the wagon and tower is about two and a half tons. On a level road a speed of from 25 to 30 miles an hour can be attained, and a gradient of one in seven can be mounted easily. Seating for five men is provided, and there is plenty of room for tools and repair material.

As a "reliability test," the car was driven from London to Newport (Mon.), a distance of about 160 miles; the journey was completed without a hitch.

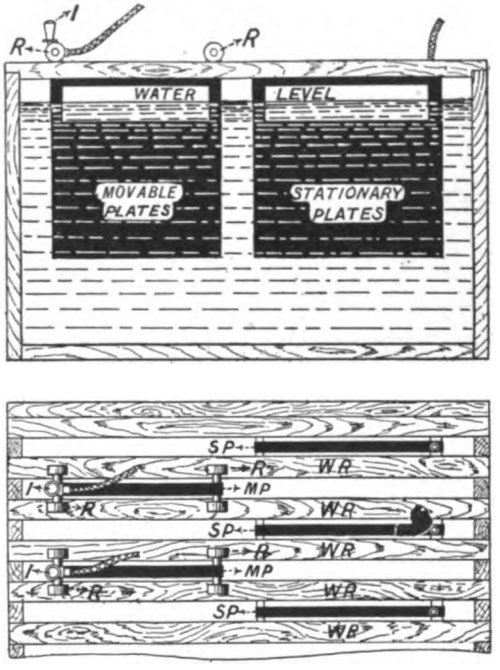

FIG. 7.—SECTIONAL ELEVATION AND PLAN OF WATER RESISTANCE.

Water Resistances

IN order to test dynamos, some form of resistance must be employed in order to obtain a sufficiently steady load. Practically the only alternative is to use accumulators in place of the resistance; but owing to the varying conditions which must be complied with in a test, accumulators could only very rarely be used in this way. In the earlier days of electrical engineering, wire coil resistances mounted on frames were used, almost without exception. These are not only costly and take up a good deal of valuable space, but also give rise to difficulties, such as sagging and short-circuiting of the coils when heated, deterioration by oxidation, etc. The range of such resistances cannot very easily be regulated without using complicated and expensive subdividing connections and switch-gear. For testing alternating current machinery, non-inductive resistances are necessary; straight wire resistances obviously take up too much space, so other arrangements, such as carbon plate rheostats, incandescent lamps, and water resistances, have been tried. Of these, water resistances have proved the most efficient, when cost and other circumstances are taken into account. The water resistance has the fault, however, that as its temperature rises the resistance falls, and the electrodes have to be moved farther apart. On the other hand, as the water evaporates the electrodes have to be moved nearer together. These faults are avoided in modern water resistances by keeping up a circulation of cool water. Though a very simple piece of apparatus can be very quickly rigged up with old casks and sheet metal plates for temporary purposes, yet a number of details have to be carefully thought out when the resistance is intended for constant use in the test house. In the foreground of the accompanying illustration (Fig. 6) are shown the water resistances for high and low voltage installed in Messrs. Bellis and Morcom's test house. Different methods of adjusting the resistance are used. In one, the plates are supported on rollers which run on the edges of the tank, so that they can easily be moved nearer together or farther apart. In another, the resistance can be altered by sliding the plates in parallel planes.

A good supply of water for cooling purposes

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is continually circulated through the tanks, by means of a by-pass from the circulating water pump used with the surface condensing plant for the engines under test. The poles of these resistances are made of cast-iron plates about one inch and a quarter thick. This thickness allows a good deal of electrolytic action to take place before the plates have to be discarded.

Fig. 7 represents a type of resistance which has proved very satisfactory. The movable plates, M P, are hung on rollers, R, which run on the wooden rails, W R, and can thus be easily brought in between the stationary plates, S P, by the insulating handles, I, I, with perfect safety to the operator. The containing tank is a wooden vessel, braced together by long stay bolts.

A resistance of this type is only suitable for voltages not exceeding 750; but at this pressure pure water would offer too high a resistance, so its conductivity must be increased by the addition of caustic potash, common salt, or sodium sulphate. Sulphuric acid would be better than any of the above, were it not for the fact that it acts chemically upon the iron plates, eating them away, and forming a non-conducting coating of gas bubbles on their surfaces. If it is desired to use sulphuric acid, the resistance plates should be made of lead.

The conductivity may be conveniently expressed in terms of the number of inches between the plates, for a drop of one volt at a current density of one ampere per square inch; a greater current density than this has been found to be unsatisfactory, chiefly owing to polarisation difficulties. If a 10 per cent. solution (by weight) of sulphuric acid were used, the distance between the plates would be one inch; if the same strength of caustic soda, 0·8 of an inch; if common salt, 0·32 of an inch; if sodium sulphate, 0·18 of an inch.

The quantity of cooling water required per kilowatt, if a rise of temperature of $t°$ F. is permissible, is $343/t$ lbs., or $343/10\,t$ gallons per hour.

The number of watts that can be continuously dissipated per cubic inch of solution, for a rise in temperature of, say, 120° F., is about two, assuming average conditions.

In designing a liquid resistance the first thing to do is to calculate the size of the plate to give a current density not exceeding one ampere per square inch; next, the capacity of the containing vessel must be arranged so that there may be at least half a cubic inch for each watt to be dissipated. A convenient strength of solution is then taken which will give the required drop of volts.

A Substance for laying the Dust on Roads and in Mines

THE development of the motor car has brought into prominence the disadvantages attendant on dusty roads. In coal mines also, the dust problem has become a serious one: several dust explosions have occurred; and in other explosions, the area of destruction has been considerably increased by the ignition of coal dust. Water, which has been till now used for laying the dust, is only temporarily useful, and may lead to trouble in other directions. Westrumite, which consists of crude Texas oil, mixed with certain other oils and resins, and with ammonia and soda, is claimed to act upon the substance of the dust, forming a sort of impermeable skin which resists the action of wet and sun, and so keeps the dust from rising after the passage of a motor-car; and also prevents the rising of the coal dust in mines, after explosions or a blown out shot.

A Valuable Albumen Reagent

A FEW drops of a saturated solution of salicyl sulphonic acid are added to 20 or 30 m.ms. of urine. A precipitate due to albumen is coagulated by heating the liquid. If proteoses only are present, the liquid clears when heated, and becomes cloudy again on cooling. No substance which occurs in urine gives a precipitate with this reagent, except it be of the proteid class. The reagent is stable, non-caustic and non-staining, and in the crystalline form is easily portable.

The Assay of Drugs

EXPERIMENTS by Dr. A. Panchaud, undertaken at the instance of the committee editing a new edition of the Swiss Pharmacopœia, indicate that in assay processes drugs should be in the finest possible powder, and should be air-dried; ether is of more general utility than mixed chloroform and ether; the proportion of solvent to drug should be about 10 to 1; ammonia is preferable to sodium hydrate; water should not be added after shaking with alkali and solvent; four successive agitations with acid are necessary; titration has no universal advantage over weighing.

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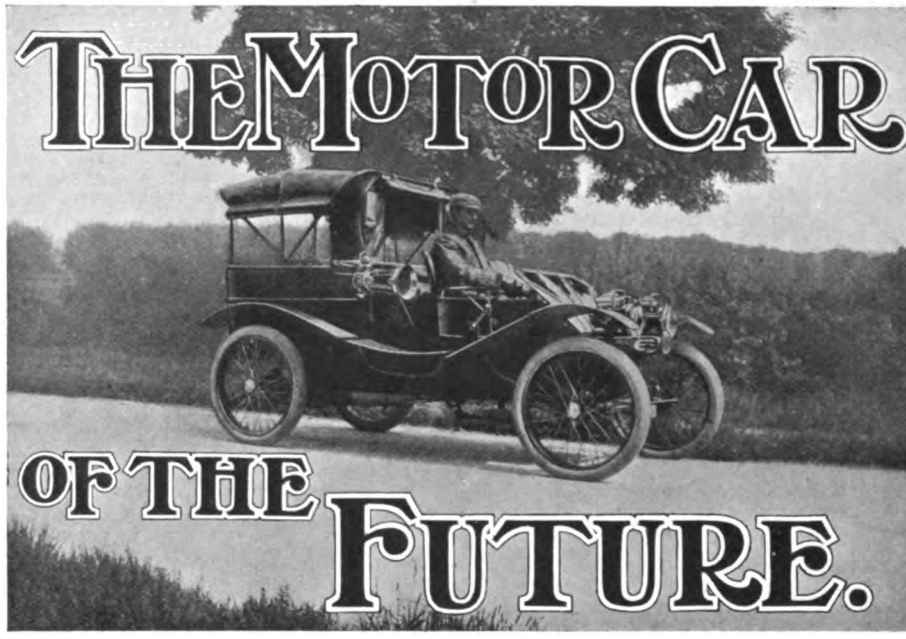

By F. W. LANCHESTER.

Introductory.

IN writing an article under the above title, I do not propose to indulge in any vain prophecy as to the ultimate goal towards which the development of the modern motor car is tending, or even to predict the more immediate developments that time may have in store.

The future of a machine so complex as the motor car, considered merely from an engineering standpoint, would be difficult to forecast with any certainty, involving as it does a study of the inter-action of a number of functionally different pieces of mechanism in the "shaking down" process necessary to the evolution of a perfectly harmonious whole; but the problem involves wider issues than those of a purely engineering nature.

In some respects the future of the motor car, and consequently the motor car of the future, is dependent on road improvement; the maintenance of good roads will be one of the principal determining factors as to the commercial possibility or otherwise of the employment on a large scale of motor cars for goods haulage. In order that any great strides should be made in road improvement and maintenance, public money must be forthcoming, and public opinion must be won over. When we are brought into contact with public opinion, we have to deal with a notoriously "unknown quantity"; at present people appear to regard the motorist as an unwelcome usurper, who ought to be made to build his own roads; rather than—which I venture to think will be the verdict of the future—the harbinger of cheap and rapid transport, with all its attendant advantages to rich and poor alike.

It would not be possible, in an article such as the present, to consider the future of the motor car broadly in all its possible and probable ramifications. I have pointed out how largely even the existence of one class of car depends on the "other half of the machine," *i.e.* the road; and how its development may be hampered or accelerated by the march of public opinion. Similarly, many other extraneous influences are at work which cannot be taken into account in a comparatively brief article. I propose to confine my further attention chiefly to the pleasure and passenger class of machine—a class which has already abundantly proved its right to existence, and to which the term motor car is more commonly applied.

I shall endeavour, in the present article, to point out the nature of the forces that are at present controlling the evolution of the pleasure vehicle, and enable the reader to gather some reasonable idea of the more immediate consequences of such influences.

A question arises in one's mind in approaching the subject from this standpoint—What is the modern car from the point of view of

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its own history? What stage of development has it reached?

It is obvious, I think, that the motor car is not of the nature of a single invention, of which the growth and development can follow its own bent, without reference to the general advance in other branches of engineering. The modern car is the outcome of a quantity and variety of experience and inventive skill that is quite remarkable. As it has, in the past, depended for its many details and improvements on the progress and advance of knowledge in many contributory arts and manufactures, so in the future we may anticipate the possibility of more or less revolutionary improvements cropping up from time to time. Such upheavals are not uncommon in the history of mechanical contrivances, generally rendering the future somewhat uncertain.

For my present purpose I shall, however, ignore the possibility of changes of a *revolutionary* character; but, taking a fairly wide view, I shall attempt to determine, from the recent changes in those features common to cars of different systems, at what stage we have at present arrived in the history of development. Are we at a period when further great change may still be expected, or is the modern car the crystallising result of a nearly completed period of evolution?

There is, to my mind, very considerable evidence to show that at present we are still very far from fixity and standardisation of type. In all such general features as length of wheel base, height and centre of gravity of bodywork, weight of car per passenger, power of engine per cwt. of car, etc., etc., the march of development has been consistently in one direction: there has been no over-shooting the mark and subsequent reaction, such as we are accustomed to notice when a period of development is approaching finality. It is unquestionably a fact that in the evolution of any new machine or other contrivance, under human agency, the final form is usually arrived at only after a certain amount of oscillation; consequently, where we find the development to have taken place consistently in *one sense*, it may fairly be assumed that the evolution of the machine is yet far from complete.

Over and above the *general consideration* stated above, it may be remarked that the more generally accepted, or French type of the present day, is admittedly somewhat of a compromise; neither the requirements of the engineer on the one hand, nor those of the carriage builder on the other, are fully complied with.

Amongst the evidences of unrest, in connection with what I think it fair to term the French type (which is most generally popular), may be cited, firstly, the modifications of engine position adopted by several of the leading makers of cars in this country, notably the Wolesley, Lanchester, James and Browne, and others; the variation being adopted principally from engineering considerations, to which reference will be made later: secondly, the bodymaking difficulties which of late have been strongly in evidence; nearly half the new bodywork shown at the last Paris exhibition was what may be aptly termed "trick" bodywork. Many and wonderful were the devices exhibited, schemed to obtain a side entrance in a "dishonest" way, where a straightforward side door would have involved a length of wheel-base that the designer was not prepared to face.

I shall return to the above questions later in my article; but think I have said enough for the moment to indicate some of the evidence in support of my conclusion, that the present type of car must undergo considerable further evolution before it finally settles down, and takes the form of the "Motor Car of the Future."

Two Points of View.

A motor car may be viewed from two main standpoints:—

(1) As a motive power installation;
(2) As a locomotive road vehicle.

A car must be satisfactory from both these points of view before it can be satisfactory as a whole. Correct design consequently requires that a nice balance shall be struck wherever the requirements from these two standpoints clash in any way.

Part I.—The Motor Car as a Motive Power Installation.

The requirements of a car, considered as a motive power installation, naturally differ with the fuel to be used and the form of prime mover employed. On the other hand, the requirements considered as a locomotive road vehicle depend to a great extent upon the duties to be performed, *i.e.* whether for pleasure, passenger conveyance, or goods transport. With regard to the latter, we have decided to confine our chief attention to the passenger-pleasure type; this at once allows us to eliminate many classes of fuel, and reduces the issue as to prime mover to within narrow limits.

I purposely ignore the question of *storage* as an alternative to *fuel* and *prime mover*, as on the one hand the only commercial form

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of storage (electrical) can be regarded as a form of fuel and prime mover, of highly specialised type and very limited capacity; and on the other, the electric (storage) car can at present be considered as a thing *sui generis*, having its own limited place in the world's locomotion.

Fuel and Prime Mover.

The first questions that arise are those of fuel and motor.

From considerations of utility I prefer to classify the different varieties of fuel as follows:—

Gaseous Fuel.—Including all fuels gaseous at ordinary temperatures, capable of storage either as compressed gas or as liquid under pressure.

Spirit Fuel.—Including all distilled inflammable liquids with a flash-point well under the ordinary prevailing temperatures.

Oil Fuel.—Including all the heavier petroleum, shale oils, etc., suitably combustible, whether distillates or otherwise; and

Solid Fuel.—Anthracite, soft coal, coke, wood, etc., etc.

Of the above, gaseous fuel, owing to storage difficulties, is not employed: spirit fuel is in almost universal use for the pleasure vehicle; and oil and solid fuels are principally employed for heavy traction.

There is no comparison, to the ordinary motor car user, between the convenience of a petrol car and that of a machine using ordinary petroleum. The one is always ready to start at a moment's notice, while the other requires many minutes' tedious preparation; the one is as quickly out and under weigh as a bicycle, the other takes longer to get in commission than a horse and trap. The petrol car is suited to the requirements of the man who keeps no servant: it is ready for instant service day or night. The steam or heavy oil car is almost useless for short runs, and practically requires a man in constant attendance.

Although the steam car using heavy oil is still a factor to be reckoned with, I think I am quite safe in saying that, so far as pleasure purposes are concerned, it will soon become extinct, at any rate in countries where spirit of any reasonable description is obtainable.

Of course, for merchandise and goods transport, it may be said to be a *sine qua non* that a car must use the *fuel of the country*. This does not necessarily mean that in England, for instance, nothing but coal is available: to a wealthy country with a world-wide trade, and a network of railways for internal transport, the fuel of the country is practically the fuel of the world; but even under these favourable conditions, for the bulk of goods transport, coal is the only fuel that can be used with a margin of profit.

Whether the employment of "coarse fuel" for heavy goods vehicles will at any time have so far developed as to compete with spirit on the pleasure car, is, for the time being, uncertain: I consider it unlikely. The question of cost of fuel in comparison with other expenses of maintenance (tyres, cleaning, replacements, etc.) is so small as to be scarcely worth consideration. The alleged danger from fire, at one time so much talked about,* has, *with properly devised arrangements*, proved to be quite infinitesimal.

I see no reason to expect any immediate development of the fuel question. The only commercial source of supply of spirit fuel at present is petroleum.

Petroleum spirit, or petrol, is produced in varying quantity at most of the oil fields, and probably no serious shortage of supply need be anticipated for twenty or thirty years at any rate. At the same time, it is generally recognised as a matter of great importance that some alternative source of spirit fuel should be discovered. Benzol (a gasworks product) and alcohol have both been suggested and used experimentally. The latter has the advantage of being capable of production in any agricultural country; but at present the question of price, and the difficulty of "denaturing" for excise purposes, are against its employment.

The possible introduction of an alternative spirit does not affect the present question seriously. A petrol engine is a spirit engine, and with slight modification is adaptable to any spirit fuel of good quality.

The Petrol Engine.

The past development of the petrol engine has been marked by a general increase in the number of cylinders. Although this is the case, the advance has not taken place to the same extent in all grades of machines; some of the earliest Daimlers were two-cylinder cars, whereas many of the cars now on the market have only one. It must be borne in mind, however, that the single cylinder car of to-day is essentially the cheap car, and one does not search for the direction of advancement in the lowest quality article.

* The only cases of fire in about 400 car-years (one car one year equals one car-year) on which I have information, are two. The fires were due to the attendant trying to fill the petrol tank, in presence of a lighted carriage lamp in one case, and of a naked light in the other; in both cases *the filler was closed*, so that petrol was poured loose over the car.

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The single cylinder, or "few cylinder," engine is admittedly a defective instrument;

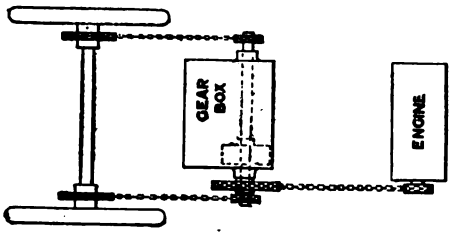

FIG. 1.—PARALLEL DRIVE.

its principal shortcomings are — want of balance, and extreme variability of torque. These defects are overcome by employing a multiplicity of cylinders, and the multi-cylinder engine may be said to be the evolutionary solution of the difficulty. There is, however, one, and so far as I am aware, only one other solution, so far as the explosion engine is concerned — that is, the reverse rotation method employed in the Lanchester car. In this arrangement perfect balance is obtained, and the torque is rendered constant, while two cylinders only are employed.

In multi-cylinder engines, as used in what are admittedly high-class cars, the range which at present finds favour is from three to six cylinders. I do not think it at all unlikely that in the future an even larger number of cylinders will be employed. Of course there

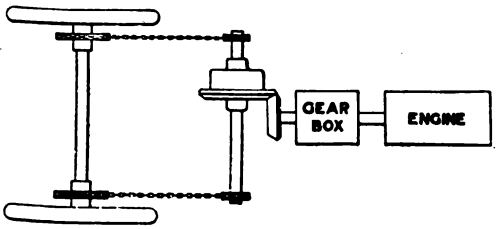

FIG. 2.—PANHARD DRIVE.

is the objection of complexity, but this is more imaginary than real; it may be a useful talking point for a salesman who is employed to sell one cylinder car, but is otherwise of no account, except so far as it affects cost of production. From the public standpoint the advantage lies, not with *simplicity of construction*, but with *simplicity of management;* and the simplest car to manage may be reasonably expected to be one of the most complex to construct. Let me illustrate my meaning. A car is simpler without a magneto-ignition, it is simpler with a hand oiler instead of an automatic lubricator, it is simpler with plain bearings than with balls or rollers, with a hand throttle than with an automatic governor, etc.; but all these *constructional complications* go to make a car *simple to handle* and a pleasure to drive. I think we may be justified in anticipating that, in spite of many simplifications that may perhaps be effected, the car of the future will at any rate be no less complicated than the better-class car of to-day.

From *general considerations*, we cannot expect simplification. It is usually admitted to be a fundamental law, that evolution involves progress from the simple to the complex, and there is hardly an example of modern machinery that does not bear out this generalisation.

I think that in all probability most of the leading features of the modern multi-cylinder engine have "come to stay." Space is too brief to discuss these in detail; such adjuncts as magneto-ignition, automatic throttle governing, positively actuated valves, may be

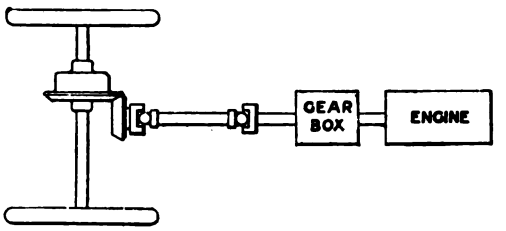

FIG. 3.—DIRECT DRIVE.

mentioned. In addition to the tendency towards an increase of refinement in detail, there appears to be a considerable movement in the direction of a greater range of engine-speed with increased maximum piston-speed, and consequently greater "flexibility" and greater power for a given weight.

The Power Transmission Train.

Taking in the first instance the general scheme of transmission, we have in Fig. 2 a plan diagram of the Panhard arrangement which appeared in the early 'nineties, and at one time was almost universally adopted. It will be noted that though this arrangement was quite one of the first in the field, it may really be regarded as a hybrid of the parallel drive (Fig. 1) and the direct right-angle drive (Fig. 3). The latter arrangement, which involves the use of a "live" axle, was employed, so far as I am aware, for the first time on the Lanchester car in 1897.

Until the Panhard arrangement showed its superiority to the then existing systems, the parallel drive (Fig. 1) in various forms was

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that most generally employed. In nearly all the early models by such makers as Mors, Benz, Bollée, were various arrangements of parallel drive. The first experimental Lanchester (1895-6) was so fitted, but with central chain and epicyclic gear. This arrangement was also used at an early date in America, where it survives to-day.

The parallel drive (Fig. 1) survives in the Wolesley, and James and Browne in this country, and in the Duryea, Cardillac, and Oldsmobile in the States; but so far as I am aware, it finds no supporter on the Continent. It is worthy of remark, that whereas the early Continental arrangements of parallel drive were mostly belt and chain, the belt has now been practically discarded in favour of either chains only, or gear and chain. The Panhard type (Fig. 2) is still employed by the firm of Panhard-Levassor, as well as a large proportion of the other leading makers; but year by year it is giving way before the direct right-angle drive (Fig. 3), which is rapidly gaining popularity.

There is one important point that touches the respective merits of the different types of transmission mechanism: that is, the question of power transmission across the suspension.

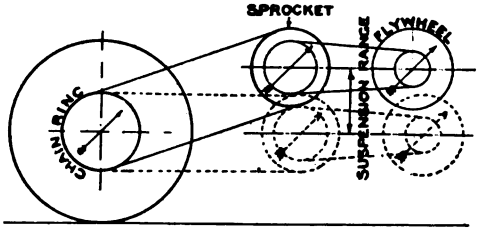

FIG. 4.—CHAIN DRIVE WITH EQUAL WHEELS.

The method of giving the necessary flexibility to the drive is essentially different in types (1) and (2) from what it is in type (3). In the former the accommodation is effected by means of the chain drive; in the latter by a special organ, the jointed coupling shaft.

The chain accommodation is theoretically bad, unless the driving and driven wheels are approximately of the same diameter. The degree of approximation necessary, as determined by practice, need not be very close. Provided that the gear ratio employed is not greater than about 2 to 3, the results would appear to be satisfactory; although no doubt smoother running is obtainable if the ratio is nearer unity.

The importance of employing equal-sized chain wheels, and arranging the whole of the gear between the motor and sprocket shaft, was pointed out by me so far back as 1896, at a time when the prevalent chain gear ratio was about 6 to 1; yet I believe that, even at the present day, many makers do not fully appreciate the nature or importance of the difficulty. I will endeavour to make the matter clear.

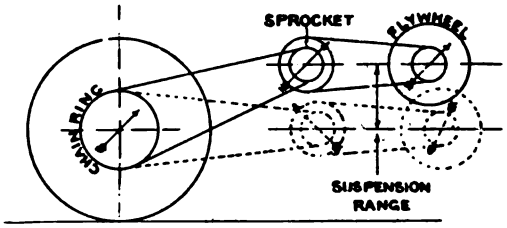

FIG. 5.—CHAIN DRIVE, WITH UNEQUAL WHEELS.

Referring to Figs. 4 and 5, we have in Fig. 4 a diagrammatic representation of a chain drive of equal-sized wheels, illustrating how such wheels acquire only a parallel motion relatively to one another when the suspension is bounced or rocked. In Fig 5, where we have unequal-sized wheels, it is at once evident that there will be considerable relative rotation under similar conditions. Now the pinion is geared to a flywheel possessing considerable inertia; and the chain wheel, secured rigidly to the road wheel, has the whole inertia of the car behind it, resisting its motion. As a result, in order that the suspension should have play, the flywheel has to be spun to and fro through a considerable angle, as indicated in the figure; when the car is driven over a rough road the chain is continually "snatching," and the benefit of the suspension is nearly neutralised. It is worth while remarking that, so far as pure "rocking" is concerned (that is to say, when one side goes up and the other down), the ordinary balance gear fitted to the sprocket shaft is able to compensate; but for "bouncing" (both sides rising and falling simultaneously) the "snatching" action is severe. In practice, the difficulty was ameliorated by allowing the chain considerable slack, and by the slipping of the clutch when the stress became too great.

Those not accustomed to problems involving superposed motions, may be tempted to express doubt as to whether the effect produced on the gear with the car at rest, will be produced when it is in motion; they may be inclined to think that with the car rushing along at full speed, the effect of which I have been speaking would be lost, or so mixed up as not to be recognisable. Such is not the case; the effect is qualitatively and quantitatively the same as

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if the suspension were asked to perform its duties with the car standing still.

It is quite evident that if the equal chain drive be employed, we require a sprocket shaft of almost as great weight and dimensions as would be necessary for the rear under-frame of a vehicle of the same size with a transmission arranged on the direct right-angle system (Fig. 3). It would consequently appear that the cost of production of the chain-driven car would be very much greater than the equivalent vehicle with direct right-angle drive, and this without any compensating advantage.

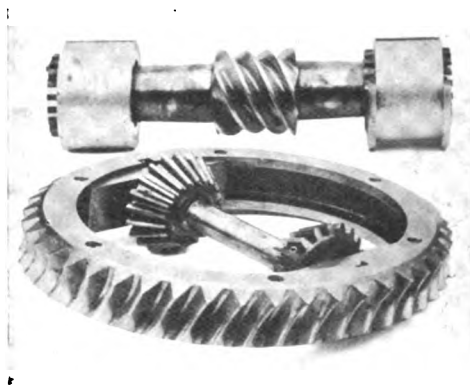

FIG. 6.—TO ILLUSTRATE THE LANCHESTER WORM DRIVE.

The subsidiary advantages of the direct right-angle drive are very great. As well as being the more direct, and consequently the more efficient arrangement, it lends itself infinitely better to good all-round design; and in addition can be made completely weather-proof without the smallest difficulty. There is but one argument that can be urged against it: this is, that it involves the use of a "live" axle, which, though not in itself a detriment, means slightly more *dead* weight on the rear wheels—theoretically a move in the wrong direction. With a long and extensive experience of the live axle, I can say without hesitation that I have been unable to detect any bad results from the cause indicated.

There is one point of difference between the Lanchester arrangement of right-angle drive and that generally employed — the worm drive (Fig. 6) in place of the usual bevel.

There used to be a tradition that a worm drive is of necessity wasteful of power. This notion has of course been long since exploded, though I believe the Lanchester car has done more towards laying that ghost in this country than anything else. Sellers in America, and Reckenzaun (1884) in Germany, had previously shown properly cut worm gear to be a thoroughly efficient transmitter of power.

Put briefly, the advantages of the worm over the bevel drive are as follows:—silence of running: symmetry and robustness of design: increased clearance for body work: possibility of floor level being lowered 6".

The last ceases to be an advantage in countries where made roads are unknown, and boulders 18" high are the rule rather than the exception. Figs. 7 and 8 show the permissible difference in position of body.

I consider that, for the home market, the worm has a most undoubted advantage; but that for some of the colonies the balance of advantage might rest with the bevel. I anticipate that both types of gear will survive.

Change Gear.

It will perhaps have been remarked that

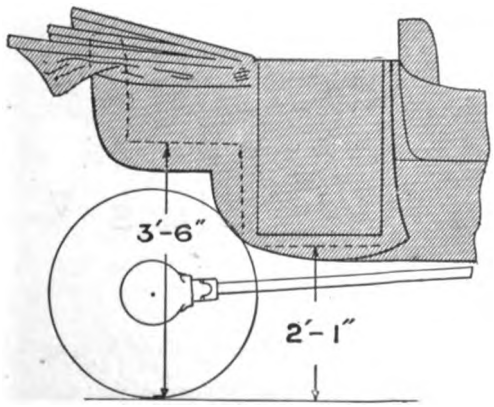

FIG 7.—BODY OF CAR, FOR BEVEL DRIVE.

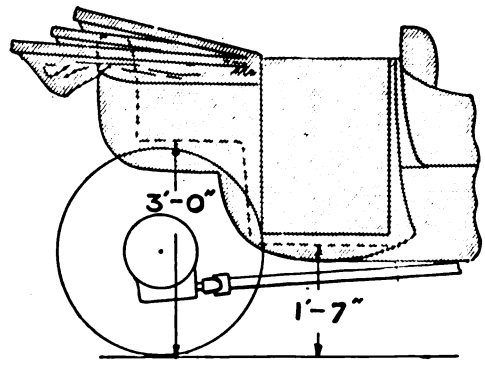

FIG. 8.—BODY OF CAR, FOR WORM DRIVE.

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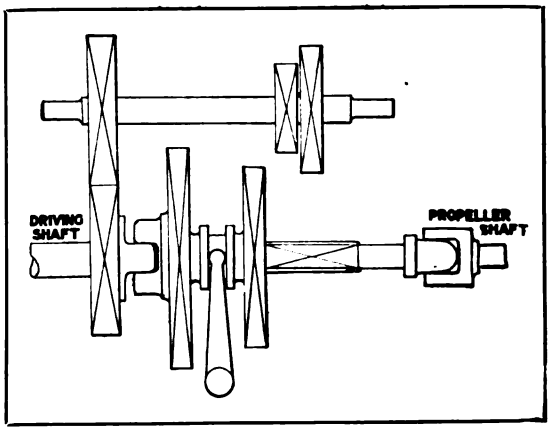

FIG. 9.—TO ILLUSTRATE "DIRECT DRIVE ON TOP SPEED."

I have so far avoided all mention of change gear in discussing the system of power transmission. I am, for my present purpose, treating it as an incident in the power transmission train, subordinate to the general arrangement.

There are two main types of change gear employed at the present time :—(*a*) intermeshing change gear, and (*b*) epicyclic change gear.

The intermeshing gear is characteristic of the French type; the epicyclic is employed on several American models, and by a few English manufacturers. One point worthy of note in connection with the change gear question is that the *system of driving* the car and the system of change gear go hand-in-hand; any alteration of the one may require a corresponding modification of the other: for this reason we may expect to find the

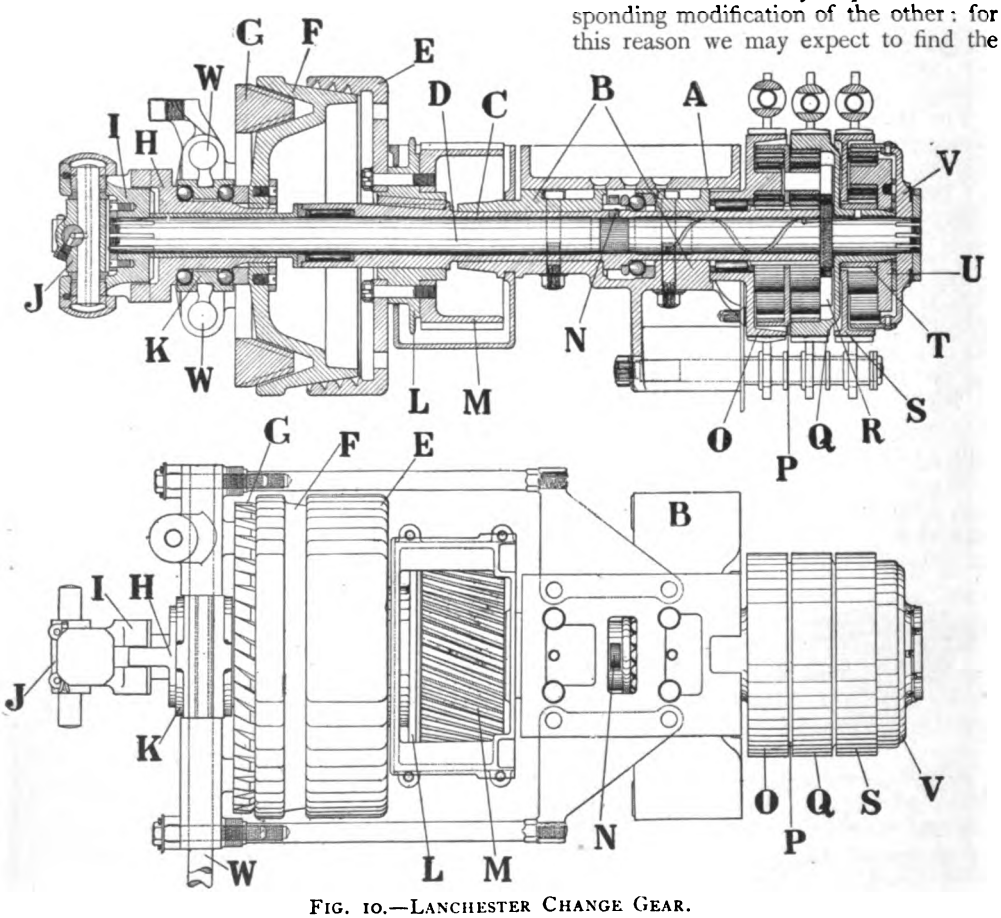

FIG. 10.—LANCHESTER CHANGE GEAR.

M. Pinion by which countershaft is driven from motor.
E. Female element of cone clutch bolted to M.
G. Fixed brake ring.
F. Male element of clutch in feathered connection to propeller shaft, can alternatively be thrown into gear with E giving direct drive, or G to actuate brake.
O. Q. and S. The actuating drums of the reverse and change-gear epicyclic trains; these are operated on by three separate "brakes" not shown fully in the figure.

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established types of change gear to persist, and any change to be of comparatively slow growth.

In the French type the power is always transmitted through the main clutch, no matter what gear is in use: that is to say, to borrow from electrical phraseology, the clutch may be said to be "in series" with the change gear.

In the epicylic arrangement, the main clutch is used only on top speed: each train of gear has the equivalent of its own clutch, so that the main clutch and gears constitute alternative paths for the power, and may therefore be said to be "in parallel." This gives the epicyclic arrangement a slight advantage: one is not dependent on the main clutch in order to get along. A further, and in fact the principal advantage of the epicyclic gear, is the ease with which gears can be changed. It may be truly said that changing gear neatly on the intermeshing system is an art that takes practice to acquire: whereas the epicyclic gear presents no difficulty to the veriest novice.

We frequently hear the catch phrase "direct drive on top speed"; this does not mean exactly what one might think. If the car happens to be of the Panhard type, the power is still conveyed through two transmissions—bevel gear and chain drive, as shown in Fig. 1. The phrase is of course inaccurate, but is generally used to imply that the change-gear is not in action on the top speed: that the gear box is "short-circuited," in fact; this arrangement is shown in Fig. 9. A disadvantage is, that although the high gear is a through drive, all the other gears require to be double transmissions, and are proportionately inefficient. The device may be described as one for "robbing Peter to pay Paul."

One of the advantages of the epicyclic arrangement is that it gives the so-called direct drive as a matter of course, without additionally penalising the lower gears. Fig. 10 shows the change-gear as fitted to the countershaft of the "Lanchester," which may be taken as an example of up-to-date practice in this direction. A full description would here be out of place, but reference to the various lettered parts will enable the foregoing remarks to be clearly understood.

It will be seen in the above, as in all well-devised epicyclic arrangements, that when the high gear is employed (that is, when E is in driving connection with F) the whole of the epicyclic gear rotates *en bloc*, and the gears, though in mesh, are neither running nor under load.

It is difficult to find sufficient material on which to form an opinion as to the future of the change-speed gear. There is certainly a tendency to a reduction in the number of changes. As the engine power continues to increase, the need for a multiplicity of gear changes diminishes; and it would appear to be quite within the bounds of possibility that two speeds will ultimately be found to be sufficient—the high gear to climb any hill, and the low gear to go up the proverbial "side of a house." If such a state of things should come to pass, the probability of epicyclic gear coming into universal employment is considerable. Before leaving this branch of the subject it may be worth while noting how entirely different the motive power problem has turned out in practice to what could have been anticipated by early workers. I remember how, so far back as 1895, I (in common, I expect, with many others) conceived the idea of abolishing the multiplicity of change gears by supplying sufficient power to go over everything "on the top." It is almost impossible now for anyone but a British legislator to put himself in the attitude of mind that was quite natural at that time; the idea we had then of the motor car was that of an improved substitute for the horse-drawn vehicle, with an all round speed of 12 or 15 and an outside maximum of about 18 or 20 miles per hour. We made our calculations and built engines accordingly, but then found that a third speed gear was still wanted *because we had underestimated the demand for speed.* Subsequent time has witnessed a series of additions to the power, to do away with the necessity of the third and fourth speed changes, and the subsequent retention of the speed change gear in order to obtain a higher maximum with the power provided.

The question naturally arises, how long will this go on? So far, we have got rid of the demand for a fourth speed; how much more power must we provide to dispose of the demand for a third?

I do not think the third speed can be well dispensed with unless at least 1½ h.p. is provided for every cwt. gross load; this would mean well over 2 h.p. per cwt. tare. Such a provision would suffice for a maximum speed of 40 miles per hour, associated with a hill-climbing capacity equal to a 10% gradient on the high gear. This may sound to some a very liberal provision, but in view of what is being done to-day, and the demand for speed that has already arisen, it does not seem more liberal than the 20 miles per hour maximum appeared in 1895.

(To be continued.)

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THE INDICATOR FOR LECTURE DEMONSTRATION.

By Professor H. L. CALLENDAR, M.A., LL.D., F.R.S.

IN an article in the July number of this magazine, I described a form of high-speed indicator, which might be used for projecting indicator diagrams on a screen for lecture demonstration; and gave illustrations of typical diagrams, showing possible defects of this type of indicator, and explaining the means by which such errors and defects might be avoided, or might themselves be utilised for purposes of instruction. In the present article I propose to give illustrations of the use of the indicator in detecting defects of the engine, and in suggesting means for its improvement.

Leakage.—One of the most serious defects which may occur in a petrol engine is leakage of gas through a badly-fitting joint or defective valve. It is evident that if part of the charge is lost during compression, the subsequent explosion must be weaker, involving a considerable loss of power. In addition to this, the heated gases escaping through the leaky joint or defective valve tend to heat the joint or the valve excessively. In order to ascend a given hill with a leaky engine, it is necessary to run with the throttle more widely open than if there were no leakage; this involves a higher explosion temperature and more overheating. Leakage through the exhaust valve or the spark plug is particularly common and detrimental. In the latter case, the porcelain insulation soon becomes heated excessively and cracks; in the former case, the valve rapidly becomes burnt and scaled. In respect of leakage, the gas engine is at a great disadvantage as compared with the steam engine. A steam engine may run very well and develop practically its full power in spite of a relatively enormous leakage, which would be absolutely fatal to an internal combustion engine. The leakage in a steam engine may often amount to as much as 30 per cent. without affecting the form of the indicator diagram, and the abnormal steam consumption may thus be overlooked, or, if detected, may be attributed to cylinder condensation. The main effect of the leakage is to throw more work on the boiler and increase the consumption of steam without materially diminishing the work done per stroke. In the gas engine, since there is no boiler to keep up the pressure in the cylinder, the effects of leakage are immediately apparent on the diagram in the diminution of compression and in the rapid fall of pressure during explosion and expansion.

The diagram reproduced in Fig. 15 shows the effect of leakage in the indicator tube, and was obtained by opening a hole one-sixteenth of an inch in diameter near the end of the tube. In this case all the pressures recorded by the indicator are necessarily much less than those actually existing in the cylinder, since the leak is between the cylinder and the indicator. This may be seen by comparing the diagram with the next figure, which was taken with considerable leakage and under otherwise similar conditions. The first part of the expansion line falls below the compression line, instead of coinciding with it, as it should if there were no leakage. Owing to the leakage, the indicator tube was well scavenged, and became filled with a stronger mixture than usual. This gave rise to strongly developed vibrations, due to explosive resonance in the tube. The pressure at the end of the expansion stroke is seen to be very low, owing to the accumulated effects of the leakage. The indicated suction pressure is much smaller than usual, owing to the direct air supply to the indicator during suction. This diagram illustrates in an exaggerated way the importance of having all the joints to the indicator perfectly tight, if accurate measurements of the pressures in the cylinder are required.

The diagram shown in Fig. 16 illustrates a different type of leakage. In this case the

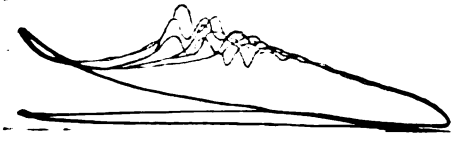

FIG. 15.—INDICATOR LEAKAGE.
10 kg. disc. Throttle, half. Revolutions, 1,500.

exhaust valve was prevented from closing perfectly by adjusting the length of the striker rod. The valve opens early, and the opening is very full, so that there is very little back pressure during the exhaust, as shown by the close coincidence of the exhaust line with the atmospheric. The valve remains slightly open during the suction stroke, and the suction pressure is comparatively small considering the speed. The engine would not run at all under these conditions unless the inlet spring was very weak and the throttle

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half open, otherwise the proportion of burnt gases sucked back through the exhaust was too large. The engine draws a very full supply of burnt and unburnt gas, but a great deal of the charge leaks away during compression, as shown by the large loop at the end of the compression stroke. When the explosion occurs the sudden pressure developed is sufficient to force the valve down on to its seat, owing to elasticity of the long striker rod, and there is practically no further leakage during the explosion and expansion, as indicated by the high pressure at the moment of release.

It was noticeable in both these cases of leakage, but especially in the second, that the engine could not be made to run slowly. In the second case it invariably stopped if the speed were allowed to fall below 2,000 revolutions, while above this speed it could

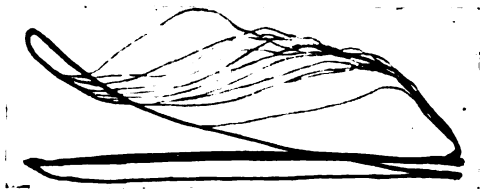

FIG. 16.—EXHAUST VALVE LEAKAGE.
10 kg. disc. Throttle, half. Revolutions, 2,200.

be made to do a certain amount of work. This is partly due to the fact that the effects of leakage are more serious at low speeds, as there is more time for the charge to escape before ignition; partly also, in the second case, to the fact that the proportion of burnt gas drawn back through the exhaust valve was larger at low speeds.

Back Pressure.—A defect of the opposite kind, namely, throttling of the exhaust, is illustrated in the next two diagrams. Fig. 17 shows two diagrams taken on one plate under similar conditions, but with the silencer entirely disconnected in one case, and with half the apertures of the silencer closed in the other. The indicator shifted slightly between the two exposures, so that the suction and compression lines do not exactly coincide, as they should; but if the lower diagram is shifted a little to the right and upwards, so as to make these lines coincide, the diagrams will be found to exhibit only a small residual difference during the first half of the exhaust stroke. The direct loss of power due to the throttling effect of the silencer (although this particular silencer was extremely efficient) appears to be practically negligible, being only a very small fraction of the power required to run the engine light. Indirectly, however, the effect of throttling the silencer is more serious, as the slower escape of the exhaust tends to make the engine hotter. Measurements of the cylinder temperatures, taken after the engine had been allowed to run for some time under the conditions named, showed that the middle of the cylinder became nearly 20° C. hotter with the silencer half throttled than with the free exhaust. This difference of temperature would be increased under full load, and might produce a very marked effect on the running of the engine.

The next illustration shows a type of throttling which is much more serious in its effects on the running of the engine, and on the life of the exhaust valve. For this diagram the exhaust valve striker was set so that the maximum lift of the valve was less

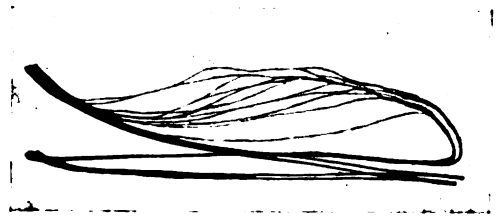

FIG. 17.—FREE EXHAUST AND SILENCER THROTTLED.
Two diagrams on one plate. Throttle, fine. Spark retard, maximum. 10 kg. disc. Revolutions, 1,500.

than a millimeter. The valve opened very late and closed correspondingly early. It was difficult to get the engine to run at all under these conditions, and it could not be made to run fast even if the spark were fully advanced at full throttle. The excessive back-pressure in this case is shown by the height of the exhaust line above the atmospheric line, which directly occasioned a serious loss of power, and was much accentuated at higher speeds. The back-pressure, combined with the early closing of the exhaust, caused so large a proportion of burnt gases to be retained in the cylinder that it rapidly overheated. The greater part of the loss of power was due, however, not directly to the back-pressure, but indirectly to the consequence that the inlet valve did not open till the piston was nearly half-way out on the suction stroke, so that the proportion of fresh mixture inhaled was small.

Errors of Timing.—The next four diagrams illustrate the effect of inaccurately timing the exhaust valve. Fig. 19 is a normal diagram taken under the same conditions as the other three, but with correct timing.

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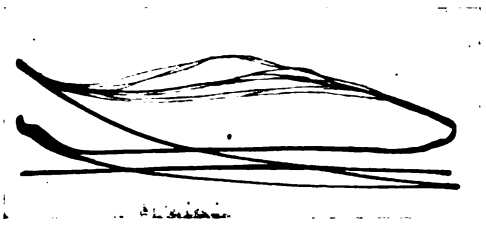

FIG. 18.—EXHAUST VALVE LIFT REDUCED.
Revolutions, 1,500. Spark advance, half.

For the diagram shown in Fig. 20, the exhaust cam was set to open and close the valve one-tenth of a revolution late. The spark lever was advanced to compensate as nearly as possible for the retardation of the spark cam, which was fixed to the same axis

FIG. 19.—NORMAL DIAGRAM.
Throttle, half. Spark retard, maximum.
Revolutions, 1,870.

as the exhaust cam. The diagram shows the exhaust valve opening near the end of the stroke, instead of at seven-eighths of the stroke, and there is considerable back-pressure at the beginning of the exhaust stroke. The loss of power appears to be chiefly due to the late closing of the exhaust valve, which causes back suction of burnt gas, and delays the opening of the inlet valve till nearly one-third of the suction stroke has been completed.

The diagram in Fig. 21 shows the effect of setting the exhaust valve to open and close one-twentieth of a revolution early. This had the effect of advancing the spark by the same amount, as the lever could not be further retarded on account of the shaft

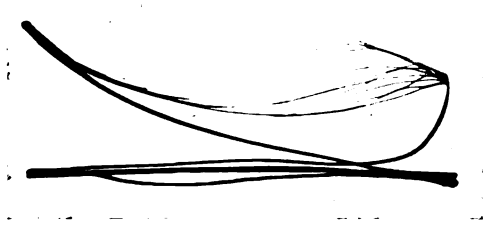

FIG. 20.
Same conditions as in Fig. 19, but exhaust valve one-tenth of a revolution late.

connecting to the indicator. The engine ran very freely and easily, but there was some loss of power, due to the early closing of the exhaust valve, which caused the inlet valve to open late, and diluted the mixture with an excess of burnt gas.

With the exhaust valve set to open and close one-tenth of a revolution early, as shown in Fig. 22, the spark was advanced by nearly a tenth of a revolution before the end of the compression stroke. In spite of this, the engine ran with great difficulty, owing to the early closing of the exhaust valve and the late opening of the inlet valve. It will be noticed that the early release causes the pressure to fall considerably below the atmospheric before the end of the stroke, owing to the great impetus of the outrush of the exhaust. In comparing the different diagrams it will be seen that the most important point in the timing is that the exhaust valve should close as near the end of the stroke as possible, and neither earlier nor later, to get rid of the burnt gases as completely as possible, and to prevent exhaust gases being drawn back into the cylinder in place of fresh mixture.

Strength of Valve Springs.—A not uncommon source of loss of power and speed in some types of air-cooled engines is the use of an exhaust-valve spring which has become unduly weakened though overheating. The loss of power in this case is due to the

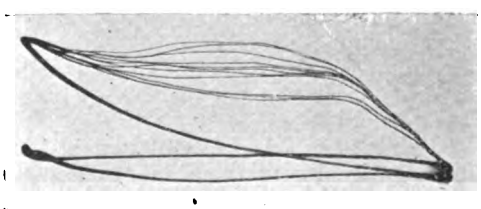

FIG. 21.—EXHAUST VALVE ONE-TWENTIETH OF A REVOLUTION EARLY.
Spark advance, half.

suction of burnt gases back through the exhaust valve. The engine cannot be made to run fast or at fine throttle, because both conditions imply a considerable suction pressure, sufficient to open the exhaust valve if the spring is too weak. If the spring is very weak, although the valve may close perfectly, and the compression show no signs of leakage, the engine will be very difficult to start, and may refuse to run at all unless the inlet spring is also very weak, or the inlet valve mechanically operated. The amount of suction leakage due to a weak exhaust-valve spring may conveniently be estimated, as in diagram, Fig. 23, by holding up the inlet

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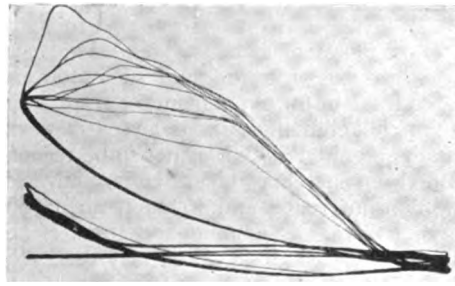

FIG. 22.—EXHAUST VALVE ONE-TENTH OF A REVOLUTION EARLY.
Spark advance, full.

valve so that it cannot open, and driving the engine by the pedals or by a motor. In this case the exhaust valve had an area of five-eighths of a square inch, and the spring was weakened so that it required a force of 3·5 lbs. to open the valve, equivalent to a pressure of 5·6 lbs. to the square inch. If there had been no leakage through the exhaust valve during the suction stroke (with the inlet closed), the compression line in the diagram would have coincided with the suction line, giving atmospheric pressure at the top of the compression stroke, instead of a compression of 46 lbs. above the atmospheric. Fig. 24, which was taken under the same conditions, shows the reduction of suction leakage effected by stretching the exhaust spring until it took a force of 7 lbs. to lift it, equivalent to a suction pressure of 11·2 lbs. per square inch. This was not sufficient entirely to prevent suction leakage, but the compression measuring the leakage was reduced from 46 lbs. to 12 lbs. By further stretching the spring to a strength of 9 lbs., equivalent to 14·4 lbs. per square inch pressure, or nearly one atmosphere, the leakage was reduced practically to zero, as shown in the diagram, Fig. 25. This diagram shows incidentally that there was practically no leakage, even at the low speed of 600 revolutions, through the piston or the inlet valve or other openings in the cylinder.

The effect of the weak exhaust spring on the running of the engine is illustrated by the diagrams 26 and 27. With the weak spring, the engine would not run steadily if the compression were reduced below 55 lbs. by closing the throttle. It was necessary to use a weak inlet spring, and the speed attained with a compression of 55 lbs. at no load, with half spark advance, was only 2,000 revolutions. With a 7 lbs. spring and the same spark advance, the compression could be reduced by throttling to 39 lbs., with a fairly stiff inlet spring, and the speed attained was 2,170 revolutions. With the spring of full strength to resist atmospheric pressure, the engine would run faster under the same conditions, or the minimum compression could be still further reduced by throttling. There did not, however, seem to be any advantage in making the spring stronger than this, as the speed of closing was ample, and it was not advisable to give the exhaust lifter too much work to do.

Exhaust Spring Lifter.—A method of

FIG. 23.—SUCTION LEAKAGE THROUGH EXHAUST.
Spring, 3·5 lbs. Inlet valve fixed.
Engine driven at 600 revolutions by electric motor.
Compression, 46 lbs.

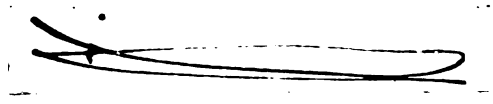

FIG. 24.
Same conditions as in Fig. 23, but spring 9 lbs. Suction leakage much reduced. Compression, 12 lbs.

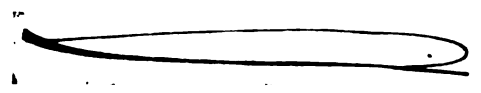

FIG. 25.
Same conditions as in Fig. 24, but spring 9 lbs. No suction leakage.

governing sometimes employed is to vary the time of closing of the exhaust valve so as to retain more or less of the burnt gases in the cylinder. A very common method is to raise the exhaust valve very slightly by means of the usual lifter, so as to allow some of the compression to escape, and diminish the strength of the explosion. A better, but equally simple method, suggested by these experiments, is to employ a *spring* exhaust lifter, which, without actually opening the exhaust valve, permits back suction of comparatively cool waste gases, and gives much smoother regulation without wasting fresh mixture. This method is actually more economical than regulation by the throttle, and is simpler for a motor cycle, since the greater part of the control may be effected by the exhaust lifter without other than occa-

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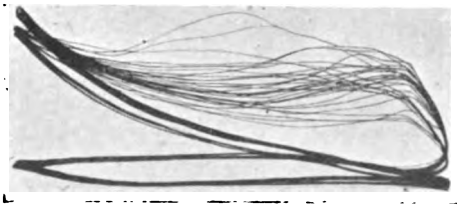

FIG. 26.—ENGINE RUNNING AT 2,000 REVOLUTIONS. Exhaust spring, 3·5 lbs. Spark advance, half. Weak inlet spring. Minimum compression, 55 lbs.

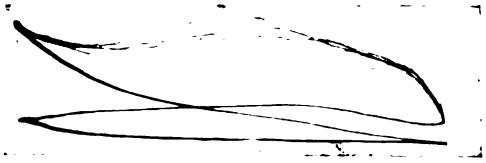

FIG. 27.—EXHAUST SPRING, 7 LBS. Stiffer inlet. Finer throttle. Compression, 39 lbs. Revolutions, 2,170. Spark advance, half.

sional recourse to the throttle, or the spark lever. It is simpler than varying the time of closing of the exhaust, and less likely to cause overheating. It is better than controlling the speed by the spark lever, because that method is very wasteful of gas, and also rapidly burns and destroys the exhaust valve. In order to apply the method, it is merely necessary to fit a spring of suitable length in the course of the wire or lever operating the usual exhaust lifter. The lift must be sufficient and the spring strong enough completely to lift the valve when required, but a very slight pressure is usually sufficient.

Inlet Valve Spring.—With an automatic inlet valve, the strength of the spring is a matter of considerable importance. If the spring is too strong, it is impossible to get enough gas into the cylinder for heavy work at low speeds. On the other hand, if the spring is too weak, the valve will not close quickly enough at high speeds, and some of the compression is lost. This defect is illustrated in Fig. 28, which was taken with a very weak inlet spring at 1,870 revolutions. At this speed the valve was occasionally still open when the piston was a third of the way back on the compression stroke. It will be noticed that when the pressure reaches the atmospheric, one of the compression lines shows a dip, and the subsequent compression falls below the normal. This limits the speed of the engine, and causes irregular firing. The obvious remedy (involving, however, additional complication, which is greatly to be deprecated) is to fit an arrangement for varying the tension of the spring to suit the conditions of running. Such an arrangement may serve also to limit the lift of the valve, and may be used in place of the throttle. I have found such a device very convenient for experimental purposes, or for stiff hill-climbing, where an extra weak spring is required; but it is not to be recommended on a dark night under adverse conditions of roads and weather, when you cannot see what is coming, and there is no leisure for tap-twiddling. You may get stuck on an unexpected gradient, with a bed of unrolled stones and mud, before you remember that you had set up the inlet tension a short way back for a fast spin on a down grade. It might be thought that a mechanically operated inlet valve would be the perfect solution of the problem; but even apart from the extra complication, it is quite an open question whether it is superior in practice to

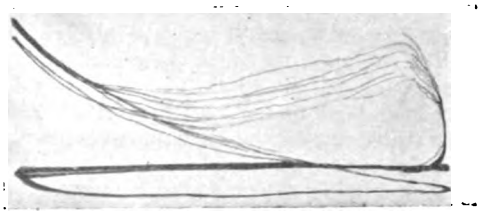

FIG. 28.—WEAK INLET SPRING. Showing occasional loss of compression.

the automatic valve for a high-speed motor. Under certain conditions the mechanically-operated valve may open too soon, or close too early, to give the best results. A good deal probably depends on the carburettor. In most cases suddenness of suction appears to be favourable to the production of a good mixture. It is also desirable that the valve should stay open as long as possible at the beginning of the compression stroke, until the pressure approaches the atmospheric. At high speeds there is necessarily a loss of pressure due to the inertia of the gas, which is shown by the diagrams to be much greater than that due to the mere tension of the inlet spring. In any case, there would be little advantage, in an air-cooled motor, where everything should be of the simplest, in fitting a mechanically-operated valve in order to get more mixture into the cylinder; unless at the same time additional cooling devices were added to get rid of the extra heat generated. But with the fan described in the April number of TECHNICS, I find the cooling so efficient, that it is worth while to consider other possible devices, such as pressure feed, for getting more power out of a given-sized motor. I hope to return to this subject in a future number.

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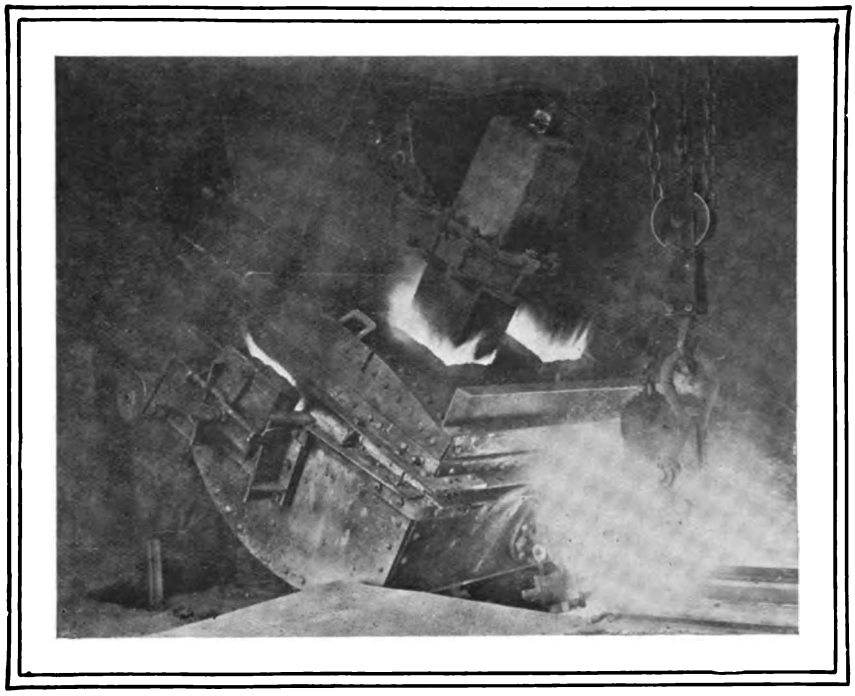
ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES.

PART IV.—IRON AND STEEL, LEAD, NICKEL, TIN, AND ZINC.

By JOHN B. C. KERSHAW, F.I.C.



THE HÉROULT STEEL REFINING FURNACE, DURING DISCHARGE.

INTRODUCTION.

IN the first and second articles of this series (see TECHNICS for March and April), the aluminium and copper industries were dealt with; and the rise of these, from the comparatively humble position occupied only thirteen years ago to the position of importance occupied to-day, was described and commented upon. It is now proposed to describe other electrolytic methods of extracting or refining metals with special reference to the production of iron and steel, lead, nickel, tin, and zinc.

It may be stated at once, that in the case of all these metals and alloys, the use of electrolytic or electro-metallurgical methods of production is at present comparatively undeveloped, and in many cases the use of electricity has not progressed beyond the purely experimental stage. The greater proportion of the lead, nickel, tin, and zinc now being placed on the market, is still extracted and refined by the older and purely metallurgical methods of production; and only in exceptional instances does one meet with any of these metals, prepared by the newer electrical processes. In the case of iron and steel, the proportion of metal won by the electro-metallurgical method is even smaller than in the case of the four metals named above.

The present developments of the electrolytic and electro-metallurgical methods which will be dealt with in this article are very limited, and are of comparatively little influence in relation to the total world output of these metals, but they are still

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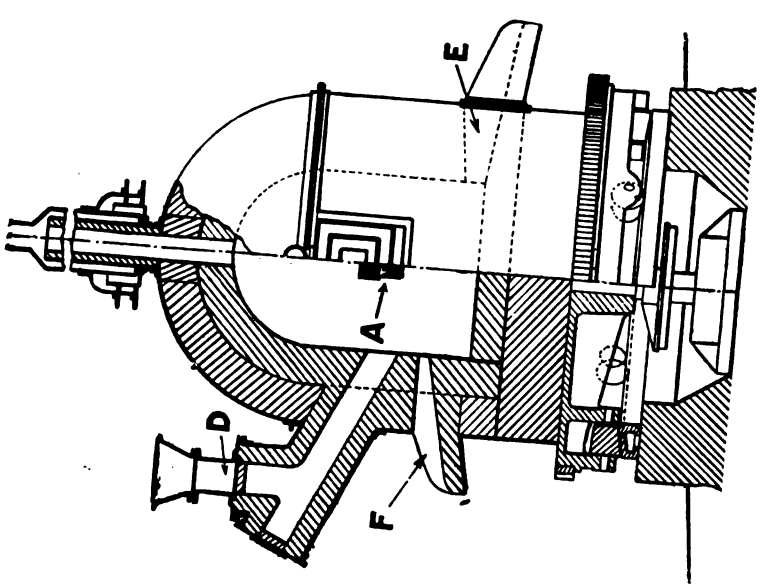

FIG. 3.—THE STASSANO FURNACE, latest form (transverse section).

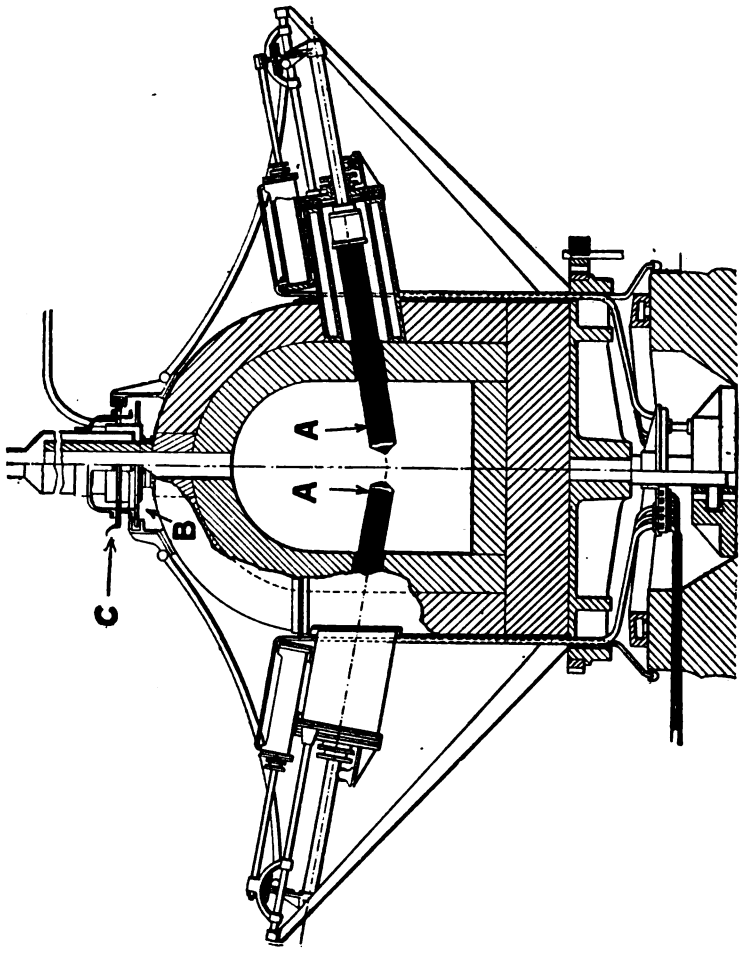

FIG. 2.—THE STASSANO FURNACE, latest form (longitudinal section).

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worthy of consideration and study; for some of the methods described are likely to play an important part in the industrial developments of the future.

As the coal-fields of Europe and America become exhausted, the necessity for finding some substitute for coke and coal in carrying out metallurgical operations will become pressing and of serious importance; and the electro-metallurgical methods of ore extraction and refining are thus certain, in time, to extend and take the place of the methods at present in use. That this change in methods of ore reduction will also be accompanied by a migration of these industries from regions of cheap coal to regions of cheap water-power, is also equally certain; and the latter years of the present century are therefore likely to witness a very considerable change in the industrial occupations of the peoples of Europe. The United Kingdom and Germany will probably once again be populated by peoples engaged chiefly in agricultural pursuits; while France, Switzerland, Italy, and Norway, by virtue of their cheap water-power, will become the manufacturing countries of Europe. Before this transfer of industries occurs, however, there is likely to be an intermediate stage of development for the electro-metallurgical processes, in which they will be employed as subsidiary operations in the usual blast-furnace procedure for making iron.

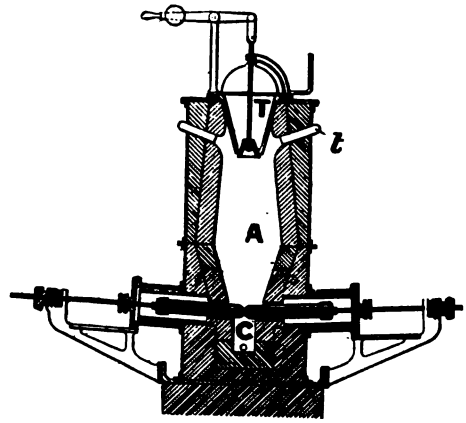

FIG. 1.—THE STASSANO ELECTRIC IRON SMELTING FURNACE.

At the present time, many hundreds of thousands of h.p. are being annually wasted, in the blast-furnace plants of Europe, with the gases which pass away from the mouths of the furnaces; and this waste has been chiefly due to the fact that, until recently, the economic utilisation of these waste gases was impossible of realisation. The successful production and operation of large gas-engines in conjunction with electrical generating machinery, has however now paved the way for the conversion of the energy of these furnace gases into a more useful form—and the large number of metallurgical processes which can be operated by aid of the electric current, indicates the lines along which this electric energy will find application.

The initial steps in this intermediate stage of development are already being taken abroad. In France and Sweden three electric steel works are now in regular operation, and in Germany an electric steel plant, operated by electricity generated from the waste gases of a large blast-furnace installation, is in course of erection. "It is an ill-wind that blows no one any good"; the introduction of electrical methods in metallurgy will thus help to prolong the life of the blast-furnace method of producing iron, although the ultimate effect will doubtless be, the disappearance of this old-established industry from the countries where it now flourishes, and its transfer in a new form, to countries more happily favoured by nature with the *houille blanche*, which to all appearances, is to be the future source of power for industrial purposes.

With these introductory remarks upon the probable lines of future development, the writer will now pass on to describe the electrical processes at present undergoing trial, for the extraction or refining of the metals named at the head of this article.

IRON AND STEEL.

Serious attempts to apply electrical methods in the iron and steel industry, only date from 1899; but already three works in Europe are regularly producing a high quality of steel by these methods, and many others are being planned. The methods of procedure may be conveniently divided into two classes—namely, that in which the ore is used as the raw material of the process, and that in which pig or scrap-iron is the starting-point. The former class includes reduction processes; the latter, refining processes. In each case the electric current is employed to provide the heat required for obtaining the iron or steel in the molten form; but in the case of the reduction processes, it is still necessary to use coke to combine with, and carry off, the oxygen of the iron ore, and so to reduce the oxide to metal.

In the reducing processes and furnaces, resistance heating is generally used; while in the refining processes, it is customary to find arc-heating employed. In each case, a large

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number of inventors have patented processes and furnaces; it will only be possible to briefly describe the more notable and successful of these in this article.

The Stassano Process and Furnace.

The Stassano furnace is the oldest of the electric furnaces for the smelting of iron ores, and has received the most extended trials. Fig. 1 shows the earlier type of furnace, and Figs. 2 and 3 show the latest form of furnace, in sectional elevation. The chief feature of the Stassano furnace is the use of the electric arc for smelting prepared briquettes, containing the ore, flux, and reducing agent. In the latest form of furnace (Figs. 2 and 3) this is combined with a revolving hearth. The carbon electrodes A, which are water-jacketted, revolve with the hearth, and the electrical contacts are arranged for by sliding brushes at B, C. The axis of the furnace is not vertical, but is inclined (Fig. 3), in order to give a mixing action to the molten materials lying on the hearth, as this rotates. The ores treated in the Stassano furnace are previously crushed, and formed into briquettes with the calculated weight of coke or anthracite, flux, and some suitable binding material.

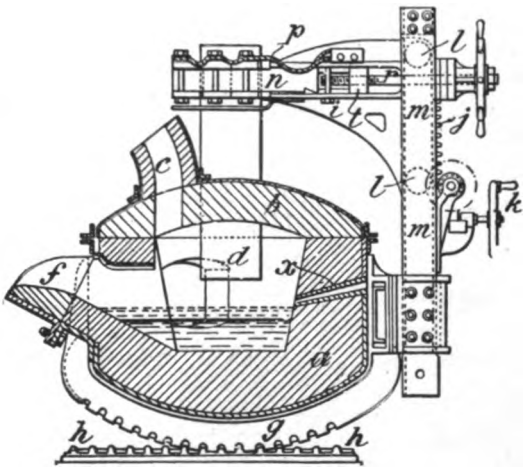

FIG. 4.—THE HÉROULT STEEL REFINING FURNACE.

The Stassano furnace and process was first tried at Rome in 1899; and as these experimental trials gave favourable results, a plant capable of utilising 1,500 horse-power was erected at Darfo, in northern Italy, in 1900. An output of 4,000 tons of steel per annum was expected from this works. In June, 1901, Dr. Goldschmidt, of Essen, visited the Darfo works, and reported that they were operating successfully.

The latest information available relating to this process, is that the Italian Government has erected a new and improved Stassano furnace at Turin, and that this is producing from 2½ to 3 tons of steel per day, of much better quality than that produced in the early trials by the process.

The Héroult Furnace and Process.

M. Héroult the French engineer, who shares with the young American inventor, Mr. Hall, the honour of the discovery and successful application of the electrical method of producing aluminium, has recently turned his attention to the production of iron and steel in the electric furnace, and has designed furnaces for both operations. Only the arc-furnace for steel production can be described here.

Fig. 4 is a sectional elevation of the Héroult steel furnace; Fig. 5 is reproduced from a photograph of this furnace as used at La Praz; the illustration at the head of this article is from a photograph of the furnace taken during discharge.

In this furnace, the heating of the charge is due to the formation of arcs between the surface of the charge and the two carbon poles; the impurities of the metal combine with lime and other suitable materials, and form a liquid slag, which is carried off.

The furnace is constructed and mounted in such a manner that it may be emptied by tipping, the slag being first poured off. If necessary, the "washing out" of the impurities of the raw iron can be completed by employing a second or third charge of suitable slagging materials. No contact occurs between the carbon poles and the metal or slag, and, therefore, contamination of the steel with silicon or carbon from this source cannot occur. Héroult has stated that by the end of 1904, furnaces of this type, having a capacity of 400 tons of steel, and a daily output of 150 tons, will be in operation in France. The Héroult furnace and process are in actual operation in Sweden, where, up to September, 1903, about 300 tons of steel had been produced. Up to the end of 1903, about 2,500 tons of steel had been produced by the Héroult method in France.

In a recent letter, M. Héroult has informed the writer that the demand for the steel produced in these furnaces at La Praz is increasing. The electric steel plant which is now being erected in Germany, for operation by electricity generated from blast-

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furnace gases, is to be on the Héroult principle.

The Kjellin and Benedicks Furnace and Process.

This process is in operation at the Gysinge foundry in Sweden; where 300 horse-power, utilised up to August 1901 in a wood-pulp factory, is now available for the reduction of iron ores. The process differs from those hitherto described, in the use of induced currents for heating the mass of scrap, ore, and coke. Fig. 6 shows the arrangement of the Benedicks furnace. The metal and ore contained in the annular space B forms the conductor, and heat is produced in this by rapid changes

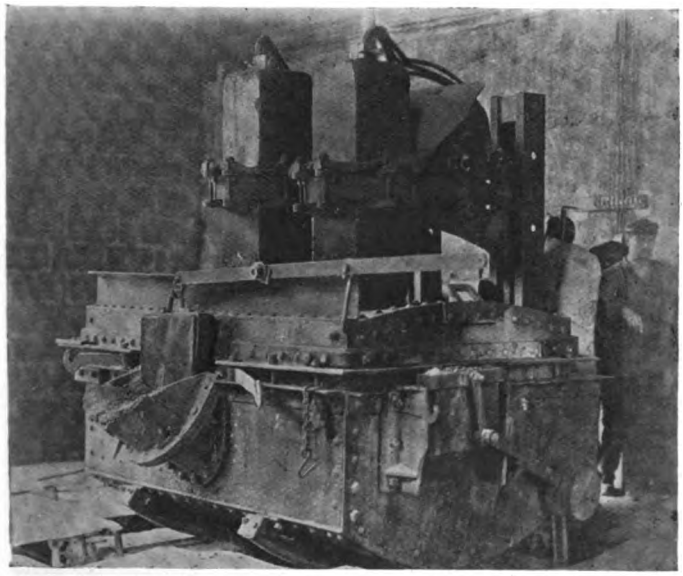

FIG. 5.—THE HÉROULT STEEL REFINING FURNACE AT LA PRAZ.

in the magnetisation of the central core D, due to an alternating current in the coil A.

The principle of the method is, therefore, similar to that which has been used for welding by aid of electricity. The furnace is reported to have been first successfully operated at Gysinge in February 1900; 270 kilograms and 650 kilograms of steel were said to have been produced in it per twenty-four hours in two trial runs. A larger furnace has since been erected at this place, and in a United States consular report, dated 1902, an estimated annual production of 1,500 tons of steel by the Benedicks process is referred to. The Spanish Government is also reported to be making trials with this furnace and process at Villa-Rubia on the Tagus, in the province of Toledo.

The original furnace used in the experimental trials at Gysinge only took charges of 1 cwt. of metal; but the furnace now in use takes charges of one ton, and has been in operation since the spring of 1902. The special advantages of the steel produced at Gysinge for tool-making purposes, are stated to be its greater ductility and softness before hardening, properties due to its high degree of purity.

The Keller Process and Furnace.

A plant for operation of the Keller process is shown in sectional elevation in Fig. 8. It consists of a reducing furnace A, constructed on the blast furnace principle, in which resistance heating is employed; and of a refining furnace B, in which either resistance or arc heating can be used. The slag from the reducing furnace flows away at C, and the metal at D. An experimental plant on the Keller principle has been erected at Kerrousse, Morbihan, in France, where 550 horse-power is available for the manufacture. The first furnace erected at Kerrousse required 375 horse-power to work it; but a larger furnace, to produce fifteen to twenty tons of steel at one charging, has since been erected. The raw material used at Kerrousse is reported to be New Zealand iron sand, from Taranaki.

Fig. 9 shows the Keller furnace in operation. A commission sent by the Canadian Government has recently witnessed the Keller process in operation at Livet in France, and has reported favourably upon the question of its introduction into Canada.

The remaining processes and furnaces for the production of iron and steel by the aid of the electric current are patented in the names of Conley, Gin, Harmet, Rossi, and Ruthenberg; but limits of space forbid any description of these in this article, or any discussion of the economic side of the question of electric iron and steel production.

Readers desiring further information on

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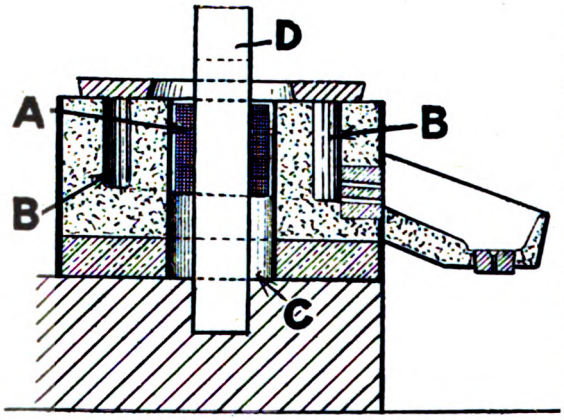

FIG. 6.—THE KJELLIN AND BENEDICKS FURNACE

the subject of iron and steel production in the electric furnace, are therefore referred to the illustrated articles in *The Engineer* of March 13th 1903, February 5th 1904, and in the *Electrical Review* (New York) of June 6th and 13th 1903.

LEAD.

There is only one process, for the extraction of lead from its ores, known to the writer as in industrial operation at the present time. This is the Salom process, which has been in use at the new works of the *Electric Lead Reduction Co.*, at Niagara Falls, since 1900. In this process galena or lead sulphide is used as cathode in an acid solution; the reduction of this sulphide to spongy lead is due to the action of the hydrogen ions, which, as they arrive at the cathode, unite with the sulphur of the galena, and form sulphuretted hydrogen gas. The process is, therefore, a chemical reduction process, in which nascent hydrogen, electrolytically generated, forms the reducing agent. Difficulties were met with in the early operation of this process, due to the escape of the poisonous sulphuretted hydrogen gas from the cells. An improved form of circular rotating cell has, however, been designed by the inventor, and these difficulties are believed to have been surmounted. Seventeen of these new cells have been erected at the Niagara works, where 500-h.p. is reported to be utilised in the manufacture. 2 lbs. of lead are stated to be obtained per e.h.p. hour, by this process.

Lead is also produced as a by-product, in an electrolytic process patented by Betts, for treating the lead bullion obtained from the silver mines of the Western States of America; this process is now employed at Trail in British Columbia.

The Betts process depends upon the use of lead fluo-silicate as an electrolyte, this compound having proved most suitable for the electrolytic separation of silver and lead. The lead bullion is used in the form of anodes, and an E.M.F. of only 0·2 volt suffices to dissolve the lead, and to deposit it at the cathode, the silver remaining insoluble and passing into the slimes. The electrolyte is made by diluting commercial hydrofluoric acid with water, and then adding pulverised quartz. The works at Trail comprise twenty depositing tanks, and are reported to be treating 10 tons of lead bullion daily. Some difficulty was caused at first by the "treeing" of the lead deposit at the cathode, but this has been overcome by the addition of gelatine to the electrolyte. Haber, in his recent report upon the electro-metallurgical industries of U.S.A., states that the commercial success of the Betts process is still doubtful, since the best method for working up the slimes and recovering the silver has yet to be discovered

NICKEL.

Although the use of nickel is extending in the arts and industries, its electrolytic production does not show any similar

FIG. 7.—THE KJELLIN AND BENEDICKS FURNACE AT GYSINGE.

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expansion. In America, according to T. Ulke, the only electrolytic process in operation is that of Browne. In this process, the nickel and copper matte, obtained by smelting the copper and nickel sulphide ores of the Sudbury district, is employed as anode material, in an electrolyte containing the chlorides of these two metals. The copper is first deposited and then the nickel; the last traces of copper and impurities being removed by an intermediate chemical treatment. This process has been worked for some years at Cleveland on a small scale, but the erection of a large works recently planned for carrying out this treatment has been suspended, pending certain changes in the nickel industry in U.S.A. Ulke states that nickel, testing 99·2 per cent. of the metal, can now be produced by the ordinary metallurgical treatment for extracting the metal from its ore; and that for most industrial purposes (as for the production of nickel steel) this metal is sufficiently pure. If this be correct, it is no doubt the cause of the delay in carrying out the plans for working the Browne electrolytic refining process on a large scale in the U.S.A.

The Hoepfner process for extracting nickel from its ores is in use at Papenburg, Germany, by the *Allgemeine Elektro-metallurgische Gesellschaft.* New Caledonian ore is said to be employed as raw material; this is leached with a solution containing cupric and calcium salts as chlorides. A solution containing both copper and nickel in the form of chlorides, with iron, lead, and silver as impurities, is obtained from the leaching vats. The latter metals are removed by chemical treatment; the solution, containing only the nickel and copper, is then subjected to electrolysis, first the nickel and then the copper being deposited at the cathode. Exact details of the manner in which this electrolytic separation is effected, have never been published, and the process hitherto has not attained great success. It was stated in April, 1902, that the output of nickel by the Hoepfner process at Papenburg was 800 kgs. = 16 cwts. per day; but the process has recently undergone modification, and possibly the output is now larger.

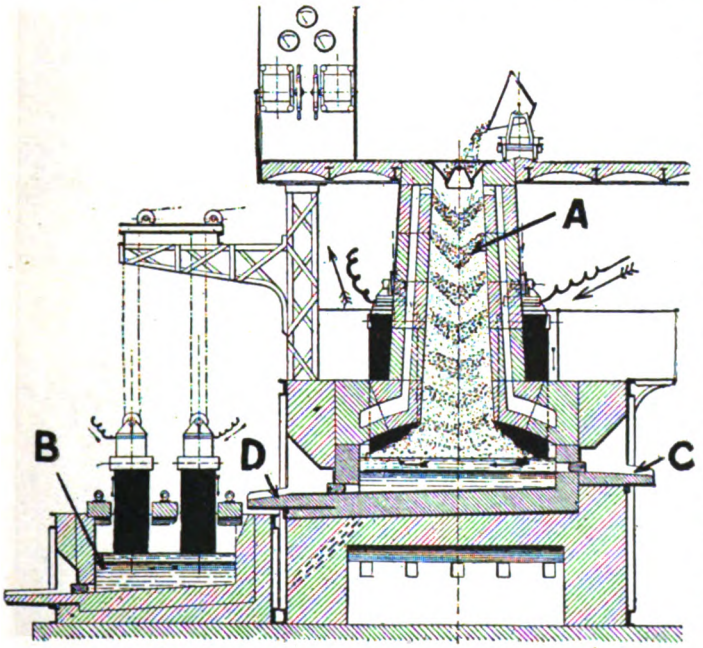

FIG. 8.—THE KELLER SMELTING AND REFINING FURNACE.

Experimental trials with direct methods of smelting ferro-nickeliferous ores in the electric furnace have been carried out in America, and details of these have recently been published by Sjostedt. So far, no industrial developments have been based upon the results obtained in these trials.

The electro-plating of nickel is, of course, a large branch industry, but this hardly comes within the scope of these articles; the production of plated goods being an entirely separate industry.

TIN.

The use of electrolytic methods in the production of tin, is chiefly confined to the recovery of the metal from tinned-sheet cuttings and scrap. The amount of tin that is annually wasted with the cans thrown away as refuse in our great cities, amounts in the aggregate to hundreds of tons; and recently successful attempts have been made to recover this tin in marketable form. The scrap-tin from the rubbish heaps of large towns, and cuttings from the factories producing the cans for tinned goods, are packed in wooden trellis-work baskets, and are employed as anodes in a bath containing a 15 per cent. caustic soda solution as electrolyte; sheets of pure tin are

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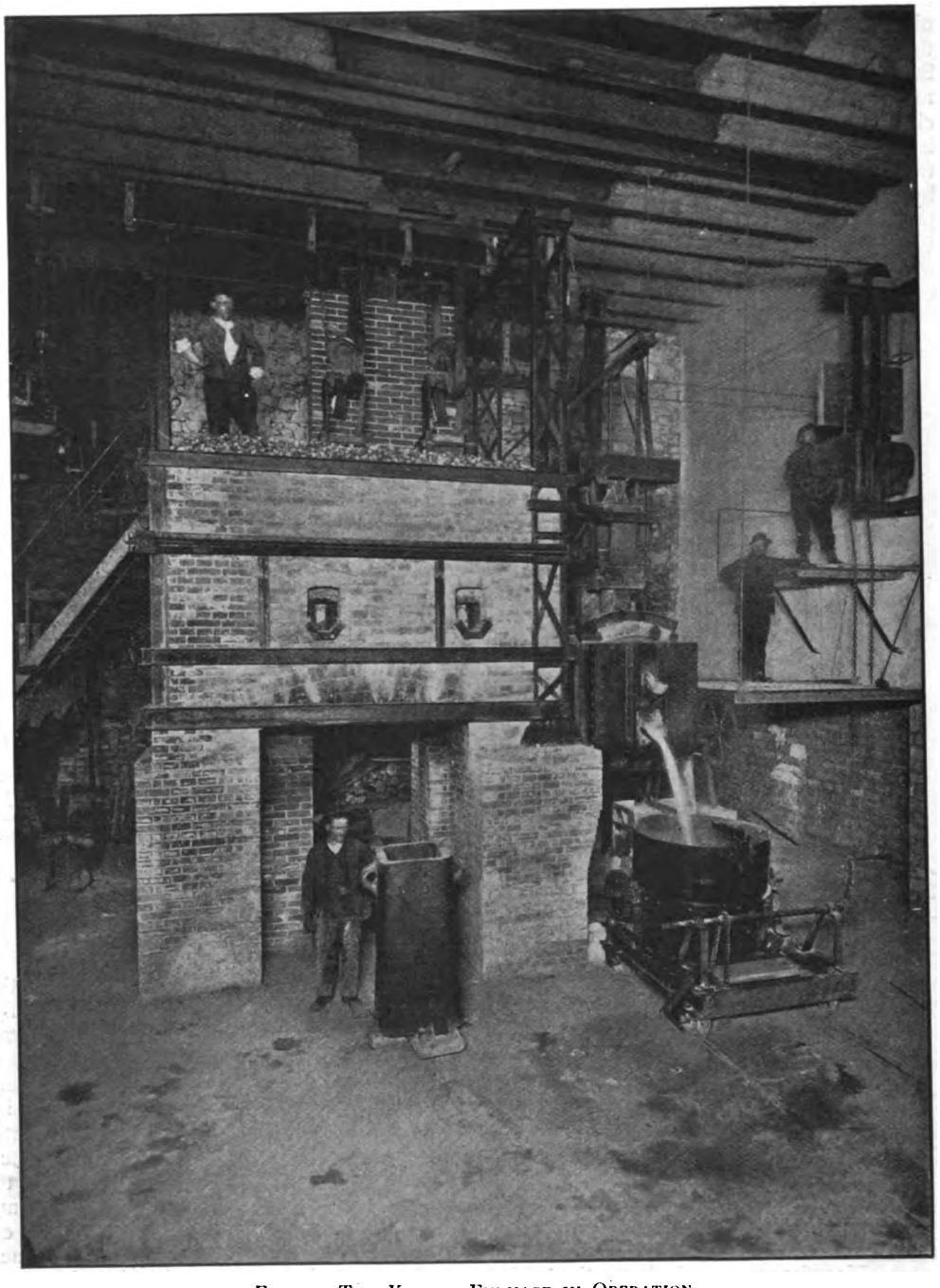

FIG. 9.—THE KELLER FURNACE IN OPERATION.

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used as cathodes. When a current is passed through such a cell, tin is dissolved at the anode and deposited at the cathode in the spongy state; and the transfer of the tin from the anode to the cathode can be continued until the original sheet of the tin-scrap is stripped quite bare. The iron remains unattacked by the electrolyte, and after washing can be used for re-smelting. The spongy tin obtained at the cathodes is washed, and then melted down into ingot form, special precaution against loss being necessary in this work. Germany has seven factories engaged in this industry, and is reported to be working up 30,000 tons of tin-scrap per annum by the electrolytic process; while similar factories have been erected, and are now operating, in Austria, France, and England. The only obstacle to further expansion in this industry is the cost of collecting the scrap tin.

At Tostedt, in Germany, an electrolytic process is also employed for extracting the tin remaining in the slags obtained in the ordinary furnace process; but no successful direct application of electrical methods in the reduction of tin ores has yet occurred.

Zinc.

A considerable number of electrolytic and electro-thermal methods of extracting zinc from its ores are now undergoing trial upon an industrial scale, and it is possible that several of these may develop into processes of industrial importance. The Swinburne-Ashcroft process, which is intended for application to mixed sulphide ores, is being operated experimentally at the Weston Point works of the Castner-Kellner Alkali Company. The process is one of chlorination, followed by electrolytic or chemical separation of the various metals contained in the mixture of fused chlorides, obtained in the first operation. It is now nearly six years since the process was first subjected to laboratory trial, and the slow and cautious development of the process is certainly a point in its favour. No figures for the output of the plant at Weston Point are, however, yet available for publication.

The Hoepfner zinc extraction process is in operation at the Winnington works of Brunner, Mond and Co. In this process the waste calcium chloride liquors produced by the ammonia-soda process are converted into zinc chloride, and this is then electrolysed with carbon anodes in a diaphragm type of cell. The process was started at this works in 1897, and the plant is now stated to be utilising 1,200 h.p., and to have a capacity of three tons of zinc and nine tons of bleach per day. Up to April 30th, 1901, 1,660 tons of zinc and 5,000 tons of bleach are reported to have been produced by it. The fall in the price of the latter product early in 1903 will no doubt have retarded the further development of the Hoepfner process at Winnington.

In France the Salgues process for the treatment of zinc ores in the electric furnace is receiving trial at the carbide works of Crampagna, in the Pyrenees. The ores used for this process contain the zinc either as oxide or sulphide, and they are smelted with fluxes which yield a slag, carrying off all the impurities of the ore. The zinc may either be obtained as metal adhering to this slag, or it may be volatilised and condensed as zinc dust. With ores containing 40 per cent. zinc and furnaces of 100 kilowatt capacity, the yield of zinc is stated to be nearly 5 kilos. per kilowatt day.

In Sweden, Norway, and the United States, experimental trials with other electric-furnace processes of zinc extraction are also in progress; but no trustworthy information relating to these has yet been published.

The electrolytic deposition of zinc upon iron, known as "electro-galvanising," is carried on at several works in Europe and America. The hot or "*dipping*" method of galvanising iron is still used for the larger proportion of galvanised articles; and the electrolytic process, which is more costly to carry out, is reserved for cases in which the absence of any heating is of special advantage.

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THE FIBROUS CONSTITUENTS OF PAPER.

No. III.—Linen.

By CLAYTON BEADLE.

Illustrated with photo-micrographs by John Christie, F.R.M.S.

THE first use of linen in the manufacture of paper does not appear to date back so far as that of cotton, at any rate so far as paper used in this country is concerned (see Technics, Vol. I, p. 567).

The Chinese have been credited by early authorities as being the first to make paper from linen; but it now appears more probable that linen was first used in Europe. The date of the first use is extremely uncertain; nor can it be ascertained whether paper was first made from raw flax or from linen rags. The Royal Society of Sciences at Göttingen, in the years 1755 and 1763, offered a premium to anyone who could trace the first use of linen for paper, but without result. The difficulty in tracing it was partly due to the gradual introduction of linen into cotton papers, and partly to the extreme difficulty (even at the present day) of distinguishing some cotton and linen fibres from one another, when the beating and bruising to which they have been subjected, and possibly the effects of time, have in a large measure obliterated their respective characteristics.

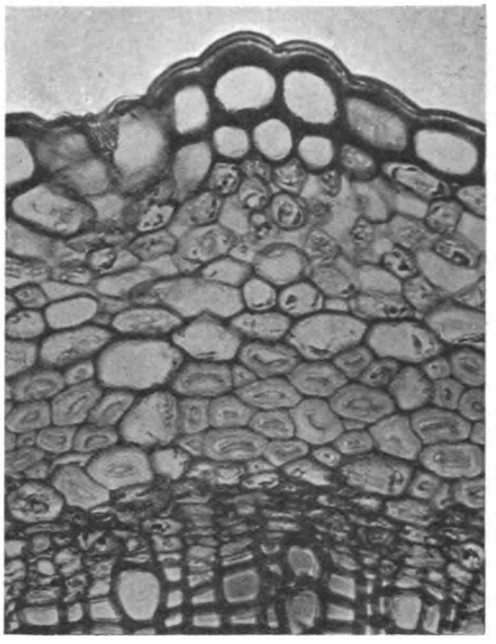

Fig. 1.—Transverse Section of Flax Stem.
Magnification 325 diameters.

It was not until Henry VII.'s reign that paper was first made in England. The first papermaker was Tate, of Hertford. Then followed the famous John Spielman, of Dartford, who made paper from cotton and linen rags; but of course paper was imported from the Continent many centuries earlier.

Raw flax has been made the subject of close scientific investigation by Cross and Bevan and other authorities. The isolated bleached fibre (linen), after the closest investigation, must be regarded as chemically indistinguishable from cotton cellulose. The bast fibre proper constitutes 20 to 25 per cent. of the entire stem, and contains portions of the wood and cortical tissue from which it is partially separated by the processes of "retting" and "scutching." The "wood" is ligno-cellulose, and the cortical tissue contains 3 to 4 per cent. of fats and waxes, and can be distinguished from the fibre by "magenta-sulphurous acid."

The flax fibre consists of pecto-cellulose, the pectic compounds being removable by alkali.

In order to obtain a pure white fibre, the above-mentioned substances have to be removed by successive treatment with dilute alkalies, bleach solutions, and dilute acids.

The component elements of the flax stem may be seen on examining Fig. 1. Taken in order from the cuticle at top, these are:—cuticular cells, cortical parenchyma, bundles of flax fibres proper, cambium region, wood.

So far as one can judge, carefully bleached linen fibre is as durable as cotton fibre; but from a paper-making standpoint the author is disposed to give the cotton the benefit of the doubt.

The character of paper produced from the linen fibre is very different from that of cotton; this is largely due to the differences in the shape and structure of the two fibres, but it is in a measure due to the liability

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that the linen fibre has to take up moisture, expand, and to work "wet" on the paper machine. This property is not peculiar to the linen fibre. The mode of beating the linen fibre for the manufacture of paper pulp, in a very large manner determines the character of the paper produced therefrom. It is necessary to distinguish between virgin fibre obtained from the raw flax, and the linen fibre derived from woven fabrics. In the former, the ultimate fibres have very marked characteristics, as seen on Fig. 4. In the latter, these characteristics are in a large measure obliterated, due partly to the large amount of chemical treatment to which the flax is submitted, first of all in the bleaching and boiling that the flax goods receive: secondly in the atmospheric and mechanical effects produced while the linen fabric was in course of wear, and the repeated washing and mangling to which it was subjected in the laundry; and thirdly, the chemical treatment to which the linen rags are submitted in a paper mill, which process resembles very closely that used in connection with the treatment of cotton already referred to.

The secondary thickening of the cell-wall of the flax fibre is not so marked in Fig. 1; but after subjecting transverse sections to chemical oxidising agents, as in Figs. 2 and 3, this secondary thickening is well exemplified. The sections furthermore show clearly the contour of the fibres, and the size of central canal, as compared with the total diameter of the cell. Contrast the sections in Figs. 1 and 3 with cotton sections shown under almost similar magnification, Fig. 8, Vol. I, p. 574, and the distinguishing contours of the cotton and linen fibres may well be appreciated.

Flax, or *Linum Usitatissimum*, is a plant having a single slender stalk about a foot-and-a-half high. The mode of isolating fibre is by "retting," or steeping the plant in water after it has been gathered and dried. The flax used by the Belfast manufacturers is generally a blend of Irish, Belgian, and Russian flax; the fibres consist of bast fibres and filaments. The length of the ultimate fibres is from 25 to 30 millimeters, diameter 0·02 millimeters; ratio = 1/1,200, compare with Esparto, ratio = 1/120. The fibre is polygonal in section, with a small central canal.

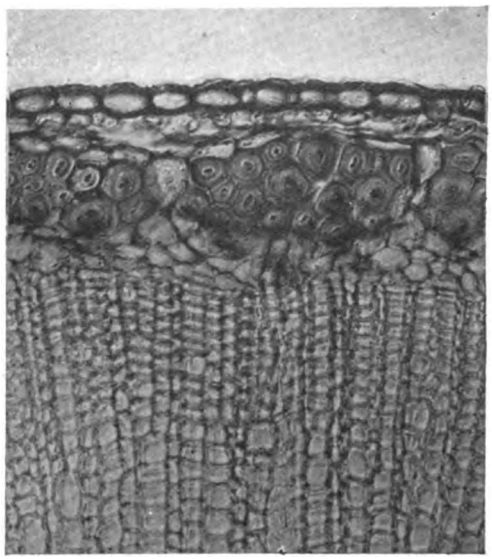

FIG. 2.
TRANSVERSE SECTION OF FLAX STEM, CHEMICALLY TREATED TO SHOW SECONDARY THICKENING OF FIBRES.
Magnification 150 *diameters.*

The location of these fibres in the stem of the flax plant is clearly shown in Figs. 1, 2, and 3; and the secondary thickening, due to the effects of chemical treatment, are very well exemplified in the two last mentioned figures.

Fig. 1 more properly demonstrates the

Reference.	Quality of Rag under Treatment.	Weight of Charge in Cwts.	Gallons of Liquor added per Cwt.	Strength of Cold Liquor (per Cent. of Na_2O).	Percentage of Na_2O on Rag.	Percentage of Free Na_2O in Solution at Different Stages of Boiling.						Free Na_2O at Different Stages of Boiling, when Total Na_2O = 100.					
						0 hour.	1 hour.	2 hours.	3 hours.	4 hours.	5 hours.	0 hour.	1 hour.	2 hours.	3 hours.	4 hours.	5 hours.
24/11	No. 2 Linen . . .	32	24	1·17	2·45	·73	·18	·145	·14	—	—	100	25	20	19	—	—
63/8	No. 3 ,, . . .	—	23	1·44	—	·90	·36	·22	·15	·117	·115	100	40	24	17	13	13
13/11	No. 2 ,, } mixed .	32	24	·91	1·91	·27	·215	·064	·025	018	—	100	80	24	9	7	—
13/11	No. 3 ,, }																
14/11	No. 3 ,, . . .	32	24	1·0	2·14	·60	·30	·12	·09	·065	—	100	50	20	15	11	—
56/8	No. 4 ,, . . .	—	25·5	1·36	—	·80	·23	·13	·12	·09	—	100	29	16	15	11	—

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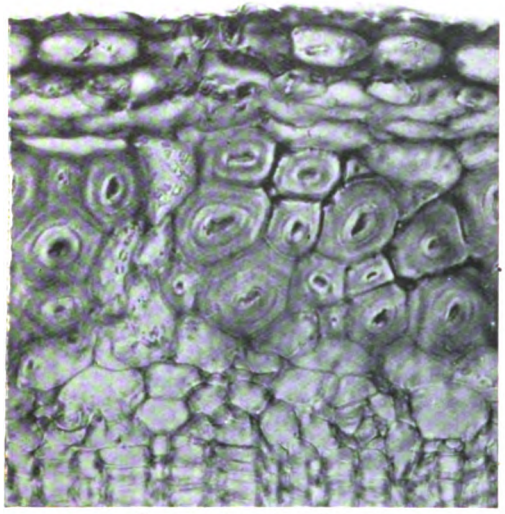

FIG. 3.—SAME AS FIG. 2.
Magnification 325 diameters.

general appearance of the fibre bundles. The chemical treatment in Figs. 2 and 3 has destroyed the starch granules and collapsed many of the cells, the intermediate cortical parenchyma occupying much less space in Figs. 2 and 3 than in Fig 1.

The methods indicated in Part II. in regard to the mode of boiling cotton rags apply equally to linen. The following table shows the conditions of boiling, and Fig. 5 shows the curves, which resemble closely those referring to cotton.

It is impossible to consider cotton without linen in the manufacture of paper, as, except in one or two isolated instances, the two always occur together. The paper made from linen would necessitate the use of very large quantities of water—more so, perhaps, than in the case of cotton. The author has had occasion to study the subject of the water consumption for different paper-making materials. It may be taken as a general statement that a "one-machine" rag mill will require 600,000 gallons per day; and that the water consumption may, and often does, rise as high as 160,000 gallons per ton of paper made. For larger outputs the consumption of water is not in such a high ratio. With a linen bank the water used for washing would be great: there would be considerable washing after bleaching, and a fair expenditure of water on the machine. The following is an instance where due economy is exercised; the table does not include water used in steam boilers, condensers, flushing, etc., but only in the actual manufacturing operations:—

WATER REQUIRED TO MAKE A TON OF LINEN BANK PAPER.

For boiling 24 cwt. of rags . . .	550 gallons
Washing five engines full for 2½ hours each at about 70 gals. per minute, say	52,500 ,,
Washing out bleach for 15 minutes at 50 gals. per minute for five engines	3,750 ,,
Water emptied with five beaters, 1,200 gals.	6,000 ,,
Water run in at auxiliary strainer, 500 gals. per hour for eight hours .	4,000 ,,
Water put in as spray on knotters .	1,840 ,,
Water used at suction boxes, couch roll and spray pipes for wash rolls .	20,000 ,,
For washing 9 cwt. of skins for size-marking	7,000 ,,
	95,640 gallons

The writer is indebted to Mr. J. W. North, A.R.A., for his experience in regard to the use of linen fibre for the finest drawing papers. He points out that there is a great difference in different kinds of linen: for artistic purposes, one linen is not equal to another. There is a great difference between paper made from new unworn linen, and that made from old long worn-linen, especially if the latter is very fine material, and has been carefully washed without using caustic soaps. This, he considers, to a great extent explains the superiority of some very early French papers, which were probably made from

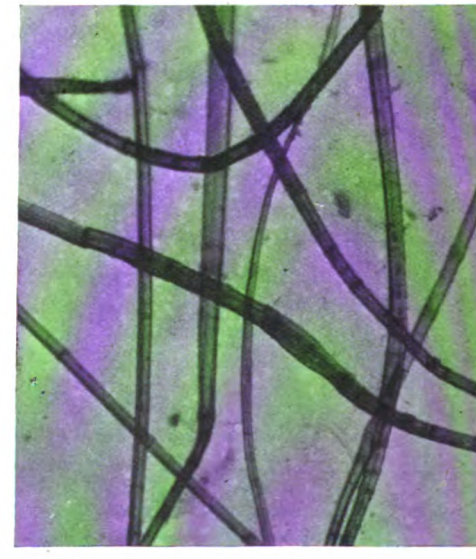

FIG. 4.—ISOLATED FIBRES FROM RAW FLAX.
Magnification 65 diameters.

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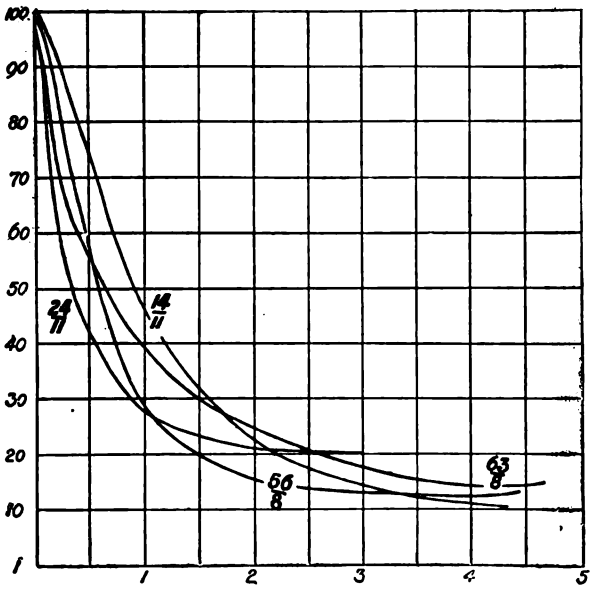

FIG. 5.—CURVES SHOWING THE EXHAUSTION OF SODA IN BOILING DIFFERENT LINENS.

sheets or body linen that had been worn for many years and cleansed with wood ash lye. Excess of toughness is not required in a paper used for the finest art printing, but *great evenness and equality in the size of the fibre.*

A pure linen paper is sized with more difficulty than one of cotton; and this has led makers to add more and more cotton to please the general body of painters in water-colours. With cotton, the quality of even absorption which saves trouble in sizing, saves trouble also in washing water-colour in even tones. It is in the highly finished work that the advantage of linen becomes manifest: the paper bears up the colour better, and the knife can be used with greater freedom. The author is reminded that it is more difficult to lock together the fibres of a long and very heavy sheet of hand-made paper than a light sheet of the same material.

Fig. 6, showing transverse section of blotting paper, and Fig. 4, showing isolated flax fibres, have been supplied by M. Marcel Rostaing, the well-known French authority, to whom the writer is indebted for numerous photo-micrographs. M. Rostaing was the first to suggest that the direction of the fibres might be determined by means of sections, proof of which was first given in Mr. John Christie's photo-micrograph of a split section of an Esparto paper which appeared in the May number of TECHNICS. M. Rostaing's photo-micrograph of the surfaces of machine and hand-made paper, published in his well-known book, would suggest to one's mind the direction of the fibres; but a surface view is insufficient, and only shows us the direction of some of the fibres, the great bulk of them being indiscernible. Quite recently, M. Rostaing has produced section of paper parallel with the surface, showing the direction of the fibres.

The question of tub sizing with gelatine has formed the subject of several communications and lectures; but in spite of all that has been written, little has been done in the way of measuring the effects of gelatine sizing upon the physical qualities of the paper. The writer, having undertaken researches with the view of throwing more light on this important branch of paper-making, intends to deal with this in the next issue.

FIG. 6.—TRANSVERSE SECTION OF TUB-SIZED WRITING PAPER, SHOWING GELATINE ON SURFACE.
Magnification 125 diameters.

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MODERN METHODS OF STEEL CASTING.

By JOSEPH G. HORNER, A.M.I.Mech.E.

(*The first instalment of this article, containing Figs.* 1-15, *was published in* TECHNICS, *No.* 7, *July*, 1904.)

THOSE who are unfamiliar with foundry work may be surprised to learn that sand in cores and moulds will interfere very greatly with the shrinkage of steel, and in a lesser degree with that of iron also. I have seen more than one large pipe, or cylinder, fractured in consequence of neglect to loosen the core in time; and flanges torn off long pipes, due to the resistance of the sand behind them. Fig. 16 represents a cylinder, or a large inlet pipe made in loam by bricking up. If this were cast in steel or iron, and left to cool without any precautions being taken, it would fracture across its diameter A, and also between its flanges B. This is prevented by laying, between the hard bricks, three or four courses of bricks made of dried loam, from top to bottom of the central core; and two or three horizontal courses of the same, around the top at *a*, underneath the flange. The flanges are also frequently stiffened with brackets, as shown in the right-hand side. The loam bricks, in some cases, are left to yield and be crushed by the shrinking cylinder. In others they are dug out of the mould as soon as the casting has fairly set, but while still red-hot: this is necessary in thin pipes.

In the pipe, Fig. 17, the hard dried sand at *a a* will prevent the shrinkage of the flanges with the pipe, and here, too, the sand must be loosened, and partly dug away before the metal cools. Brackets are also often cast on as shown at the left hand, as a source of strength. In Fig. 11, if cast in steel, the interior sand should be loosened and a portion dug away: the same thing should be done just behind the flanges of Figs. 12 and 13.

The effect of mass on shrinkage is often learned from accidental fractures and wasters. A stout casting will resist shrinkage strains to which a thinner one would succumb; so that the question of easing a mould, or of stiffening a casting with brackets, or radii, becomes closely related to the mass of the metal. Thus, a cylinder (Fig. 16), if 2 inches thick, would be twice as strong to resist shrinkage stresses as one only 1 inch thick. The reason lies mainly in the extra strength, and correspondingly greater elasticity, of the metal. But, besides this, there is a difference due to the more rapid chilling effect which takes place on thin than on thick metal. The chill penetrates quickly in thin, with consequent hardening, rapid setting, and brittle tendencies—evils to be avoided in castings.

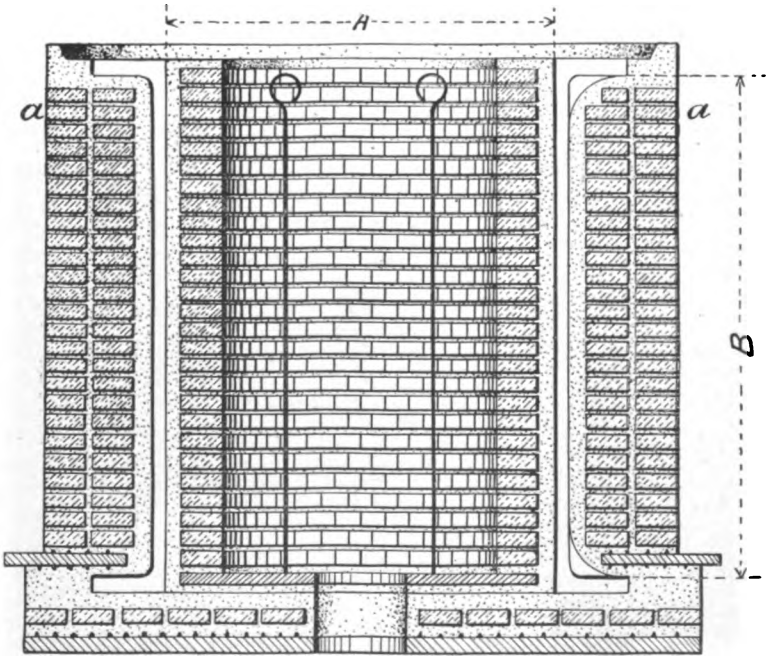

FIG. 16.—A BRICKED-UP LOAM MOULD (WITH COPE REMOVED) TO ILLUSTRATE RESISTANCE TO SHRINKAGE.

That the importance of shrinkage is not exaggerated, may be seen from a moment's considera-

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tion. Say it amounts to $\frac{1}{4}$ inch per foot; that, on a casting only 6 feet in dimensions, would equal $1\frac{1}{2}$ inches. If this is hindered, clearly the casting must stretch to that extent, which is impossible; or it must do the other thing—fracture.

Fig. 18 shows the difference between a safe and an insecure design. Above the line *a a* the design is suitable for cast iron, but unsafe in steel, which would be "drawn," as indicated. Taking out a considerable amount of metal at *b* renders the design nearly uniform in section.

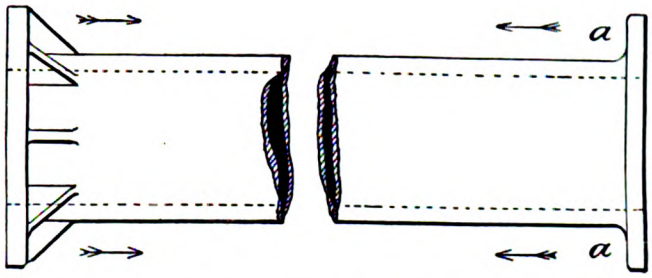

FIG. 17.—PIPE FLANGES, WHICH ARE LIABLE TO FRACTURE.

Wheels and wheel centres are cast in large numbers in steel. One example, Fig. 19, will illustrate the differences already noted in other castings. The lower portion of the figure is a design suitable for iron; the upper is suitable for steel, having strong arms, larger radii, and a thinner boss and rim. Provided they are well proportioned, these wheels seldom give much trouble, as they are mostly below 2 feet 6 inches in diameter.

Casting parts together not only interferes with shrinkage, but often causes a thickening of the metal in angles, quite sufficient in amount to cause sponginess like that shown in Fig. 15. Though this alone may not be sufficient to cause immediate fracture, or to produce incipient cracks, the open porous metal is a perpetual, but hidden menace when under strain; while in castings subject to fluid pressure it is a cause of leakage.

To cast big lugs, bosses, and brackets on otherwise plane framings, which can be done in iron, is most injudicious in steel, for they will distort the casting in the most favourable circumstances; while in bad cases they cause incipient cracks, or even absolute fractures. Fig. 20 illustrates a design which, cast in steel, gave much trouble. It is a brake ring cast on the arms of a toothed wheel, and it produced much distortion. This was got over by casting the ring separately, and bolting it up to a circular facing, Fig. 21. It involved extra work in the turnery, but was a good job.

A very important difference between casting steel and iron is seen in the cross sectional area of the ingates, and runners required. Steel cannot be poured safely through ingates so small as those which are used in iron, because the metal is liable to congeal before the mould is filled; hence the reason for the enormous ingates seen in Figs. 2, 10, and 14. The following is the explanation of the difference in steel and iron in this respect. Pig-iron is fluid in proportion approximately to the amount of free carbon that it contains, a fact which is strikingly apparent in the difference between grey iron, and the mottled and white irons. A white iron, in which the whole of the carbon is combined, and a mottled iron, in which a considerable proportion of this element is in the combined condition, are both much more sluggish than grey iron, which contains its carbon in the graphitic or free state. This difference is apparent both in the ladle, and in pouring. Steel low in carbon approximates to the condition of

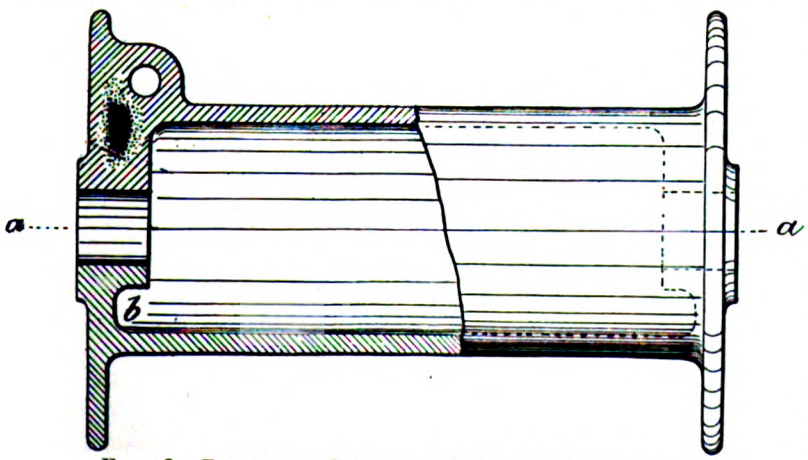

FIG. 18.—DESIGN FOR IRON (ABOVE) AND FOR STEEL (BELOW).

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white iron, and to that of viscous wrought iron; hence the difficulty of pouring it in thin sections. Steel, "chilling" quickly, fails to fill a mould properly unless large deep runners are used—large, to fill the mould quickly; and deep, to afford pressure, or "head" to the metal. Taking an extreme example, it would be impossible to pour either steel, white pig-iron, or heavily mottled iron, into the moulds for rain-water pipes; neither would be fluid enough to fill such moulds. Only the grayest iron, containing about 4 per cent. of graphitic carbon, will fill such thin moulds.

But the filling of a mould is only one of the reasons why large ingates are used. A large deep ingate acts as a "shrinkage head," or "sullage head"—the "head metal" of the moulder. The mass of hot metal in it affords a supply to the shrinking mass of the casting below, and itself retains the sullage or dirt, the light and impure metal that would otherwise go down into the mould. The steel caster makes use of very large shrinkage heads—much bigger than the iron founder requires, but with the same objects in view. In many steel castings (*e.g.*, solid pinions, stamps, etc.), there is as much head as casting, or more; and it is only by the adoption of this device that sound metal can be obtained. The heads are sawn, or turned off, and they contain the light, open, spongy, dirty metal; while the castings receive only the sound metal. The large heads, indicated in Figs. 2, 10, and 15, may have from six to eight times the sectional area of those used on iron castings of similar form.

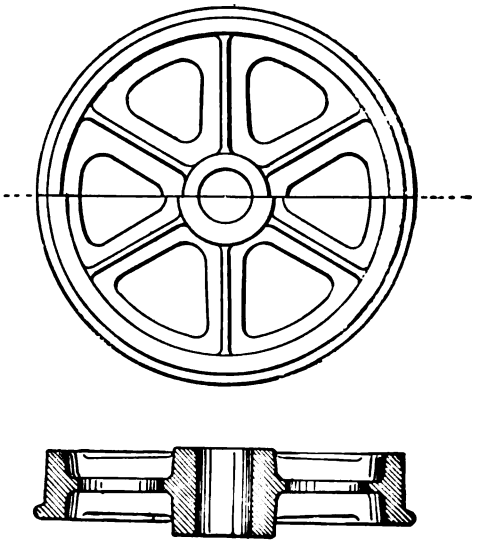

FIG. 19.—DESIGN FOR IRON AND FOR STEEL.

But the remedy of a big head will be worse than the evil it is designed to correct, unless it is applied with judgment. A great mass of metal, as we have pointed out, shrinks beyond the normal, and distorts adjacent parts. Heads are therefore put on the more massive portions of castings; never on a slender rim, or arm, or plate. If this is not practicable, then several smaller heads or runners must be substituted, which is frequently done.

Steel castings are subject, in a much greater degree than those of cast iron, to two other evils: intense hardness, especially on and near the surface; and to blow-holes, and general sponginess. Both these evils were very pronounced in the early days of steel casting, so that between these, and excessive distortion, many castings had to be scrapped. Intense hardness is reduced by annealing. The sponginess is lessened by the practice of casting good heads on, and dead melting of the metal. Thin castings generally suffer more from blow-holes than thicker ones do. As these holes are mostly below the surface, they are seldom discovered until surfaces are being planed or turned. Steel firms frequently, for this reason, rough-tool doubtful castings before sending them to their customers. Slight honeycombing in some non-vital parts of steel castings should not be allowed to condemn them. It is generally practicable to secure sound metal in vital portions by casting those downwards.

Annealing consists in exposing castings for several days (more or less) to temperatures of from 800° to 900° C., according to the mass of metal, and the percentage of carbon present; and then cooling them gradually. In this way the castings are rendered tough, internal strains are relieved, and they are easier to tool. If tested, the ultimate strength is found to be lessened, but the elongation, and contraction of area, are increased: in short, the castings are much better suited for working on, and for constructional purposes, than they would be if used just as they are turned out of the sand.

There are three methods of melting steel for foundry use:—in crucibles, Bessemer converters, and open hearth furnaces. Each system includes a field so immense that our remarks relating to them must be very brief, and absolutely restricted to their bearings on the particular subject of this paper.

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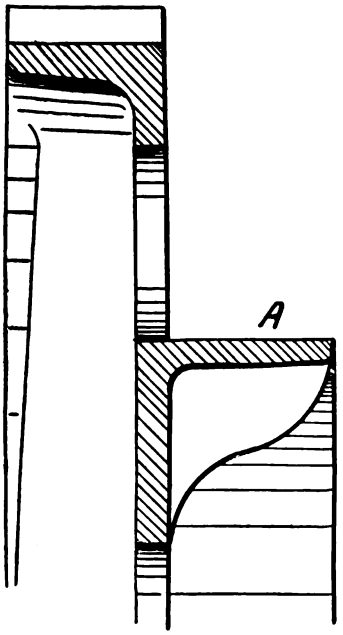

FIG. 20.—A DESIGN WHICH DISTORTS AND STRAINS A CASTING IN STEEL.

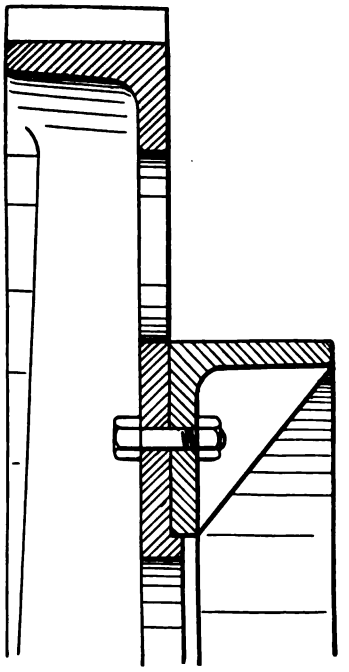

FIG. 21.—AVOIDED BY CASTING RING SEPARATE FROM WHEEL.

The case of some very small castings excepted, crucible steel-work, in England, is confined mostly to the manufacture of cutlery steel from raw blister bars, which are broken up and melted in crucibles, in order to render the metal homogeneous. Small castings made in this way are expensive. Yet, at Krupp's, in Essen, big cannon have been cast from crucible steel for eighty years past, the product of several hundred crucibles being used for casting a single gun. The great advantage of this method of casting is that an exact chemical composition can be ensured, because the contents of the closed crucible suffer no contamination from without. Whatever the mixture is that goes in, the same comes out, and, therefore, though costly, it is a trustworthy process. But it is used only to a slight extent for ordinary castings.

The second method is that of the Bessemer converter. Here the molten pig, emptied from the cupola into the converter, has its impurities burnt out by the action of the oxygen in the air blast which is forced through the metal. The sulphur, manganese, silicon, and carbon are thus oxidised, and a nearly pure iron left, in a quiescent state; carbon and manganese are added in the exact proportions required, in the form of alloys of these elements with iron, as spiegeleisen or as ferromanganese.

It is not difficult to understand the weak points of this process, which were for a time so serious, that they well-nigh wrecked the Bessemer invention. One difficulty is, that of recharging the metal with the precise quantity of carbon and manganese necessary; the other is the impossibility of oxidising phosphorus in a converter unless lime is added to the charge to form a basic compound therewith. The anxieties and labours which have beset inventors in connection with these two difficulties are writ large in the history of steel-making. The elimination of phosphorus gives by far the greatest trouble, and it explains why British steel-makers have to bring half the ores they use from abroad, chiefly from Bilbao.

To overcome the difficulties inseparable from the Bessemer process, was the object of the open-hearth methods. Briefly, these contain provisions in the linings of the furnaces for deoxidising the crude metal, in a process sufficiently prolonged to enable the melters to grade the degree of purity of the metal exactly. During the process, samples are taken and subjected to a rough analysis, and not until the precise proportions of metalloids desired are secured is the steel tapped from the furnace. The principle of operation is identical with that in the converter: that is, the foreign elements are first burnt out, and the carbon and manganese then added in alloyed forms. Acid and basic linings are also employed. But the ultimate product is under more perfect control, resembling in this respect that melted in crucibles. But while the crucible holds a hundredweight or two, the open-hearth furnace deals with several tons; and if the product is not quite so superfine as that of the crucibles, it is capable of minute regulation, measured in a few tenths, say, of 1 per cent. of metalloids.

The superiority of the metal produced in the open-hearth and the crucible, to that in the converter, is mainly due to the element of time, which enables the caster to more thoroughly oxidise the impurities, and to more quickly recharge the bath of metal.

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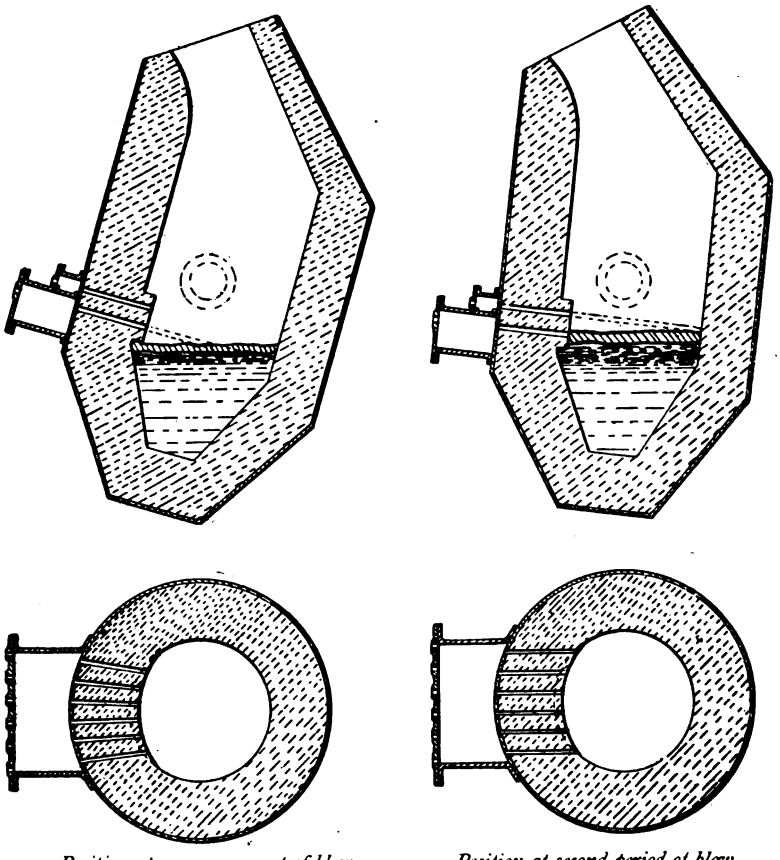
For shells, wheel centres, trolley wheels, and the harder class of castings, the Bessemer answers well; but for electrical work, slenderly proportioned castings, rudder frames, and propeller blades, and bosses, stern frames, and those in which a high degree of ductility is required, the open hearth is more suitable.

The Bessemer and open-hearth processes, therefore, practically divide between them the production of metal for the steel foundries. But specialisation and improvement have always been busy around these main operations, and we must as briefly as possible explain how the practice of steel casting is being modified at the present time.

Although the Bessemer process is now carried out substantially as it was forty years ago, numerous improvements have been effected in the mechanical details of the work. One alone concerns us here: that, namely, of the adaptation of converters to the wants of the makers of small steel castings. The common converters are well adapted for massive work, but the metal is not hot or fluid enough if used in small charges.

The most recent advance in this direction is the Tropenas process, in which a high temperature, and great fluidity, are obtained by a method of surface oxidation: that is, the blast is caused to act upon the *surface* of the metal, instead of being forced into or through it. The converter bottom is made in the form of an inverted truncated cone, so offering a large upper surface for oxidation. The metal is taken from the converter direct, and that which remains retains its heat until required. The sectional diagrams (Fig. 22) illustrate the action of the Tropenas converter during the first and second blows. There are two rows of tuyeres, a lower and an upper. The lower tuyeres are termed "tuyeres of reaction," because the direct action of the air blown through them is on the surface of the molten metal, causing the upper layer to be directly oxidised. The gases which come off as a result are then burnt, the upper row of tuyeres (the "tuyeres of combustion") being brought into operation by tilting the converter. The high temperature produced in this operation is beneficial. At the same time air is blown by the lower tuyeres through the loose slag formed on the surface.



Position at commencement of blow. *Position at second period of blow.*

FIG. 22.—TROPENAS CONVERTER.

The Robert process, and the Walrand Legénisel processes arrive at the same end by different designs and methods, and it appears that steel equal in quality to that produced in the open hearth is produced in these small converters: besides which there is the great advantage that several blows can be obtained in a day, against one only in an open-hearth furnace. As little as ten cwt. of metal can be produced at a time

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in a Tropenas converter, against say, five, or six, or eight tons in an open-hearth furnace. For small shops this is a great point in favour of the new methods. The small converter, or "Baby Bessemer," is also a valuable ally to the open-hearth plant: the first for small castings, and the second for the ordinary run of large work.

The Tropenas system has been in use at the works of Edgar Allen & Co., Ltd., of Sheffield, since 1892. Twenty of these plants, with fifty converters, are running in Europe; and nine plants, with thirteen converters, in the United States and Canada. With regard to one of these, the statement was recently made that over 700 blows had been made without a hitch occurring.

The system of multiple moulding—that is, of casting superimposed moulds—has been adopted with much success in small steel castings, weighing from a few ounces to a few pounds. As many as 500 small castings have been made in this way at one pouring in multiple moulds.

The Tropenas process, while adapted primarily to the making of small castings weighing from a few pounds to a ton or so, is also adaptable to heavier work in the absence of an open-hearth plant. This is done by collecting the steel of several blows in a ladle, from two converters alternately, a "heat" occupying about twenty minutes. Castings of several tons weight can be made with metal which has been standing in the ladle for two hours, due to the high temperature and fluidity obtainable by the process.

The relative positions of the three furnaces used, the crucible, the Bessemer, and the open hearth, may be concisely summarised thus.

The crucible method is suitable for the production of small castings, but its high cost relatively to the weight of castings produced, precludes its extended use commercially. When cost is no object, crucible steel has been used for the biggest ordnance made. The Bessemer converter is suitable alike for large and small castings; but one difficulty is that all the matter must be tapped quickly, which is often inconvenient, and is not suitable at all for small work; further, the metal soon becomes sluggish, and there is great risk of "wasters" in consequence of the metal not filling thin sections of moulds. Absolute uniformity of the metal is also not to be depended on. The open-hearth furnaces are capable of producing steel of a very uniform quality; but with this exception they share in the objections to the Bessemer converter. The whole of the metal—six or eight tons or more—must be tapped at once; and therefore is not suitable for small castings. It answers admirably for large castings, and is the furnace most generally employed.

The design of many large ladles used for pouring steel is similar to those used for filling ingot moulds. Iron and brass founders invariably pour from the lip of the ladle, taking the metal therefore from the top. The steel founder more often pours from the bottom of the ladle, taking the metal from the locality where it is most dense. The metal by the Tropenas process can be poured perfectly fluid from the lip of a ladle, and the castings do not require to be annealed.

As the shrinkage of iron, though variable, is less than half that of steel, averaging $\frac{1}{8}$ in. in 15 in., it follows that often the same patterns cannot be used for the two classes of moulds. There are cases in which a difference of dimensions in small articles matters little, as (say) in truck or trolley wheels. But in others, as in gear wheels, brackets, cheeks, or frames that carry bearings required at exact centres or "over-all" dimensions to fit other parts, separate patterns must be made if the castings are to be produced, sometimes in iron, sometimes in steel. There is often real economy in making two patterns, because weight can be lessened in steel, either to give equal strength with that of iron, or an excess of strength. Apart from this economy, it is better from the point of view of good design, to modify the proportions of adjacent parts for iron and steel respectively, on the lines which I have endeavoured to make clear in the foregoing paragraphs.

The amount of shrinkage of steel, though always large, is variable; which sometimes causes trouble in castings made from the same patterns. Castings also turned out in one foundry may measure larger or smaller than those ordered from another, or differences will occur in the same foundry at different periods. This is due to variations in the chemical constitution of the metal, and to variations in the temperature at which it is poured: since the hotter the metal is, the more it has to shrink in the cooling.

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THE DIESEL ENGINE.

By A. W. OPPENHEIMER.

IN 1893 Mr. Rudolf Diesel began experimenting with a view to finding a more efficient prime mover than existing oil, gas, or steam engines.

Mr. Diesel succeeded in doing this after four years of hard work, by building an internal combustion engine on the following novel principles:—

RUDOLF DIESEL.
From a painting, by permission.

1. Attaining the temperature necessary for the combustion of the fuel by mechanical compression of air, previous to, and quite independent of, the introduction of the fuel into the cylinder.

2. Substituting a single adiabatic compression for the combination of isothermal and adiabatic compressions in the Carnot cycle, for the following reason:—

By a single adiabatic compression, the required temperature is reached at a pressure of 30–40 atm. On the other hand, with a four to one isothermal, followed by an adiabatic compression, the same temperature is reached at a pressure of 200 atm., which pressure would give rise to practical difficulties.

3. Gradually introducing the fuel in a finely-divided state and thoroughly mixed with air, into the highly heated air, at such a rate that the temperature during combustion remains as nearly constant as possible.

4. Using a large and definite excess of air to ensure the perfect combustion of the fuel.

Contrary to expectations, the first engine built on these principles showed that a water-jacket was necessary. Although jacketing lowers the efficiency, it thickens up the diagram considerably; all sharp corners on the diagram are rounded off, so that in the whole cycle there is no sudden change in pressure, thus ensuring steady running.

The greatest difficulty encountered in

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the first attempts was to design a suitable fuel-valve. At that time engineers thought that the only method of thoroughly pulverising the fuel was to force it through successive layers of fine wire gauze, which were liable to clog. Later on, it was found that a number of fairly large but carefully arranged holes gave equally good results without clogging.

Even in the early engines, the combustion was found to be so perfect that crude and unrefined oils were consumed with ease.

Diesel engines have been running successfully on the Continent for the last six years, and so far back as 1899, Prof. Unwin, F.R.S., after careful examination, pronounced the engine to be entirely out of its experimental stage.

So much has been written about Mr. Diesel's experimental engines, that to refer to them here would be merely repetition; the author, therefore, proposes to describe the engine in its present stage, in which crude petroleum is used as fuel.

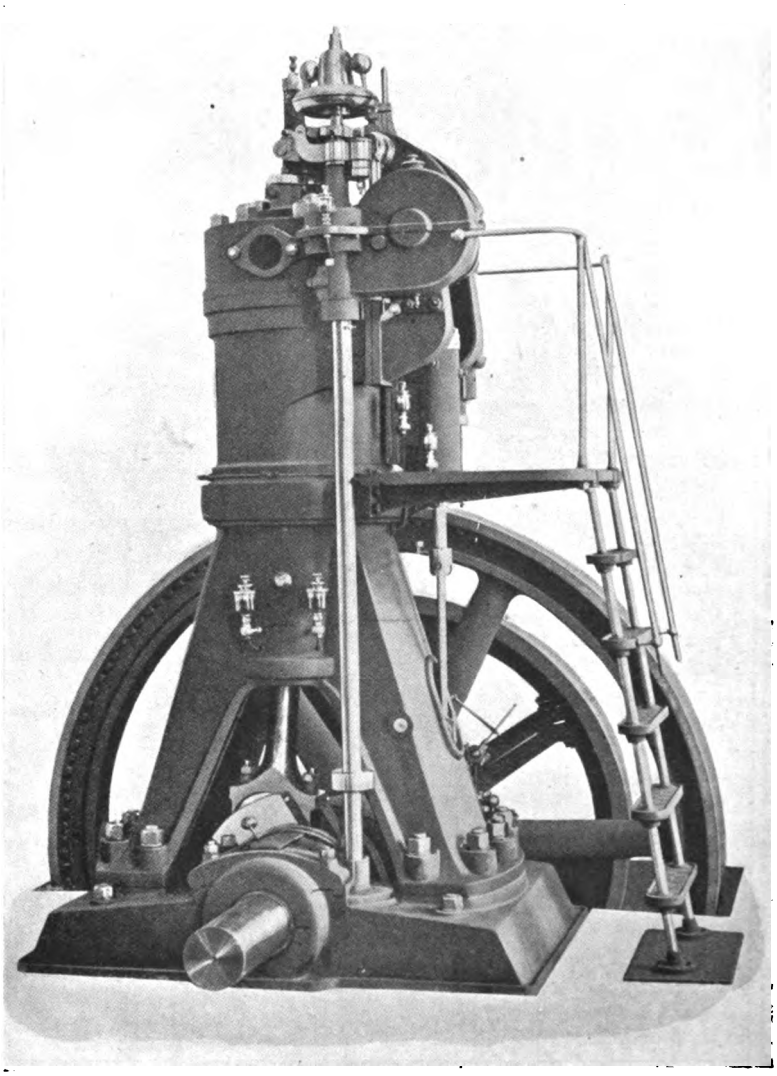

FIG. 1.—80-H.P. DIESEL ENGINE.

The task of developing the engine was undertaken abroad, chiefly by the Maschinenfabrik, Augsburg; Carels Frères, Ghent; and Sulzer Bros., Winterthur, who have succeeded in constructing a most efficient, trustworthy, and steady-running prime mover.

It is built vertical, is four stroke, and may be of the one, two, three, or four cylinder type.

DESCRIPTION OF ENGINE.

The main details of a modern Diesel engine (Fig. 2) are:—

A vertical cylinder liner, made of very hard, close-grained cast iron, fitted into a substantial frame, the space between the two serving as a water-jacket. The vertical frame is bolted to a stiff bed-plate in the ordinary way. The long open trunk piston carries six lap-jointed rings, and has only enough clearance to allow for expansion. The connecting rod turns the solid crank-shaft, to which a flywheel, made in halves, is attached by means of two wrought iron rings. The inner edge of the flywheel rim is provided with teeth, so that the engine can be brought into the starting position by a barring gear.

The cylinder cover, which is well water-jacketed, is securely bolted to the frame, the

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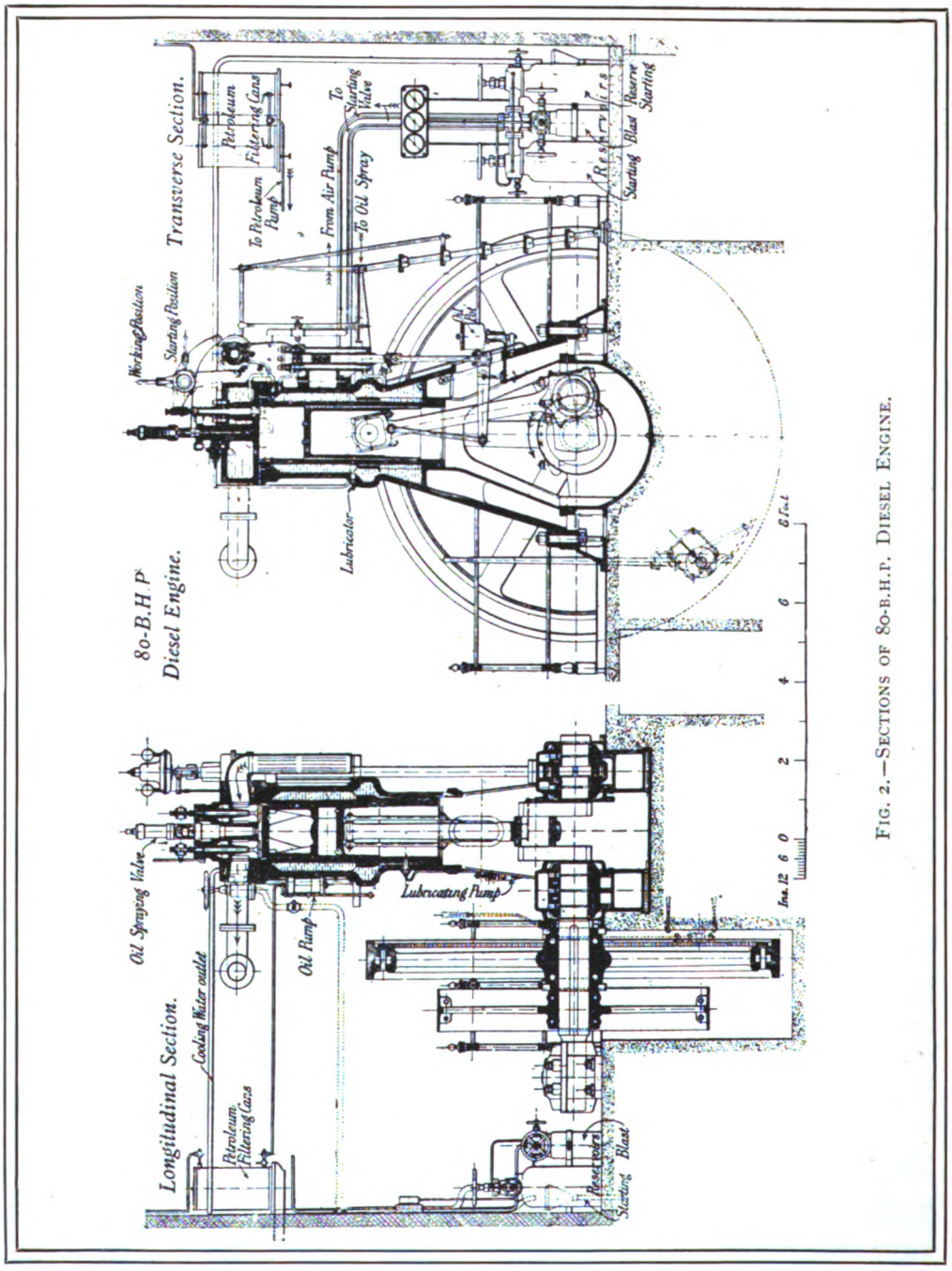

FIG. 2.—SECTIONS OF 80-B.H.P. DIESEL ENGINE.

joint being made with an asbestos ring. The cover carries the four main valves: the air-inlet valve, the fuel valve, the exhaust valve, and the starting valve. The three former are opened every two revolutions by means of rocking levers, actuated by cams keyed to a half-speed shaft. The air-inlet, exhaust and starting valves are of the ordinary mushroom type, and open downwards. The fuel valve will be described later. The rocking levers for the fuel and starting valves can be turned on an excentric axis: in one position

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of this, the starting lever is on its cam; while in the other position, the fuel lever is on its cam, and the starting lever out of action. Thus, according to the position of the excentric, either the starting or the fuel valve opens, but it is impossible for the two to open together. I shall refer to this arrangement later, when describing the starting of the engine.

Driven off the end of the cam shaft is the petroleum pump, which forces oil to the fuel valve, in quantities controlled by the governor, according to the load on the engine.

Mounted at the back of the cylinder is a water-jacketed air-pump, driven off the small end of the connecting rod by links, a rocking lever, and connecting rod. This air-pump is of ample dimensions, and can be throttled so as to fill the cast steel reservoirs with air at any required pressure. The smaller reservoir is used for injecting the petroleum

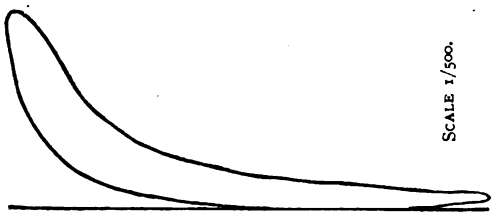

Fig. 3.—Full Load Diagram.

into the cylinder; one of the larger ones is used for starting the engine, the other being kept in reserve.

The governor is mounted on the vertical intermediate shaft, and is of the ordinary loaded type.

The crankshaft bearings are bushed with white metal, and are provided with ring lubricators. White metal is used to line all the bearings, except the cross-head bearing, which is made of phosphor-bronze to stand the heat.

The lubrication of the piston and small-end presents no difficulties. At the end of the down stroke, a force pump delivers gas-engine oil to the piston at six equidistant points in a horizontal plane, and on the up stroke this oil is distributed over the liner. This injection takes place between the first and second rings, so that no lubricating oil comes into direct contact with the flame. At the same time, the force pump delivers oil into a groove in the piston, whence it is conducted through a channel to the small end.

Cycle of Operations.

The cycle of operations is as follows:—

1. *The Suction Stroke.*—The piston travels downwards, while the suction valve is held open by its cam, and pure air at atmospheric pressure and temperature is drawn from the engine-room into the cylinder. The cam allows the valve to close after the end of the stroke. This quantity of air in the cylinder is constant for all loads, and is never throttled.

2. *The Compression Stroke.*—The piston travels upwards, all the valves being closed, and compresses the air into a very small clearance—about $\frac{1}{16}$ of the total volume. This compression is, of course, neither isothermal nor adiabatic, as it takes place in a partially conducting cylinder surrounded by a water-jacket at a temperature of about 140°F. It follows very closely, however, the equation

$$P V^{1.3} = C.$$

At the end of the stroke, the air has attained a temperature of about 720° F., and a pressure of 500 lbs. per square inch.

3. *The Power Stroke.*—Slightly before the dead centre, the fuel valve begins to open, and a steady spray of petroleum, pulverised into very small particles and thoroughly mixed with air, is injected by highly compressed air from the blast reservoir. Since crude petroleum, in the presence of air, takes fire spontaneously at about 450° F. (232° C.), and the temperature of the air in the cylinder is 720° F. (382° C.), the petroleum burns completely before reaching the piston or cylinder walls.

The fuel valve is opened only very slightly, so that all the oil cannot pass the narrow orifice at once; the injection lasts about ten per cent. of the down stroke, during which period the pressure remains practically constant.

At full load, the temperature at the end of the combustion period is about 1050°C.—considerably lower than the temperature reached in a gas engine during explosion.

When the fuel valve is closed the products of combustion expand, doing work and being cooled thereby. The expansion curve approximately follows the equation

$$PV^{1.2} = \text{constant}.$$

Before the end of the stroke, when the pressure has fallen to about 30 lbs. per square inch, the exhaust valve is opened, and release takes place into a silencer.

4. *The Exhaust Stroke.*—The piston travels upwards, expelling the products of combustion. The exhaust valve and pipe are made so large that there is practically no back pressure. In order to expel the exhaust from the clearance, a scavenge is resorted to. Before the end of the stroke the

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air-inlet valve is opened. This sets up a convection current. Cold air entering through the inlet valve sweeps out the hot gases through the exhaust valve, leaving the clearance full of pure air by the time the dead-centre is reached. This enables an engine of given size to develop more power, since the amount of oil which can be injected

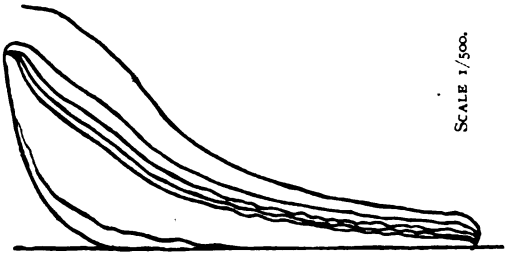

Fig. 4.—Starting Diagram.

without smoke depends on the quantity of oxygen in the cylinder.

As to the excess of air, Professor Ade Clark, in his trials on a Diesel engine running at full load, found that 48·2 lbs. of air passed through the cylinder while 1 lb. of petroleum was burnt; whereas 14·56 lbs. of air would suffice to burn it completely. Thus 3·31 times the necessary quantity of air was used.

The exhaust gases are quite invisible, except when the engine is running light; they will not discolour a piece of white paper held in them for several minutes. Consequently, the exhaust valve and the interior of the cylinder remain in good condition, and very seldom want cleaning.

When running, the engine requires little attendance. The only thing which has to be nicely regulated is the blast pressure, which should be varied according to the load, in order to get the best shaped diagrams. When running light, 100 lbs. per square inch above that in the cylinder suffices, but at overloads 400 lbs. per square inch surplus pressure is required.

Starting the Engine.

The engine is started in the following way:—

Assuming the lubricators filled, the jacket water running, the petroleum tanks filled, the petroleum pump charged, and minor details in order, the engine is brought into its starting position: that is, the crank is adjusted to be about 10° past the upper dead-centre, at that revolution when the starting valve opens. The excentric is now pulled down, so that the starting valve opens, and the fuel valve is out of action. The cylinder is closed by taking the hook off the inlet valve. The blast and one of the starting air reservoirs are then opened. Compressed air at about 700 lbs. per square inch enters the cylinder through the starting valve, and drives the piston down: this air admission lasts a considerable percentage of the stroke.

The next stroke expels this compressed air.

The third stroke draws in air from the atmosphere.

The fourth stroke compresses the same.

As the cylinder is probably cold and the speed of the engine low, the temperature of this compressed air would be too low to ignite the fuel if injected. The engine is, therefore, allowed to make about four power strokes with compressed air, the temperature rising each compression stroke as the speed increases.

After about eight revolutions, the excentric is put up. This brings the fuel valve into action, and stops the opening of the starting valve. A heavy charge of petroleum is injected and ignites, the temperature being now high enough. The engine then continues its cycle as an oil-engine, and as soon as it has picked up its speed, the load may be put on. A smart man can be driving his load about 50 seconds after starting: the initial preparations occupy less than a minute.

The Fuel Valve.

This valve (Fig. 7) is placed in the middle of the cylinder cover; in the centre is a needle valve, of which the seat has been carefully ground into the casing, the stem being well packed above. It is opened vertically upwards by means of a spherical joint on the end of a bent rocking lever, and closed by means of a powerful spring. This

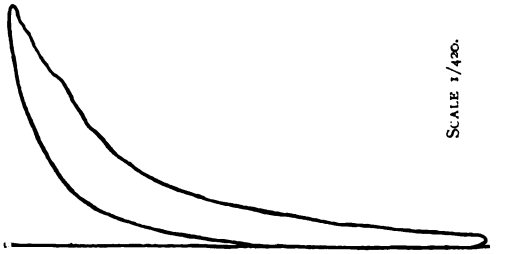

Fig. 5.—Small Load Diagram showing Isothermal Combustion.

needle runs freely through the pulveriser, which consists of a nozzle provided with vertical slits, and four rings placed one above the other and kept about $\frac{1}{8}$ inch apart by distance pieces. These rings contain a number of fairly large holes about $\frac{1}{12}$ inch in diameter. The holes in the first ring are

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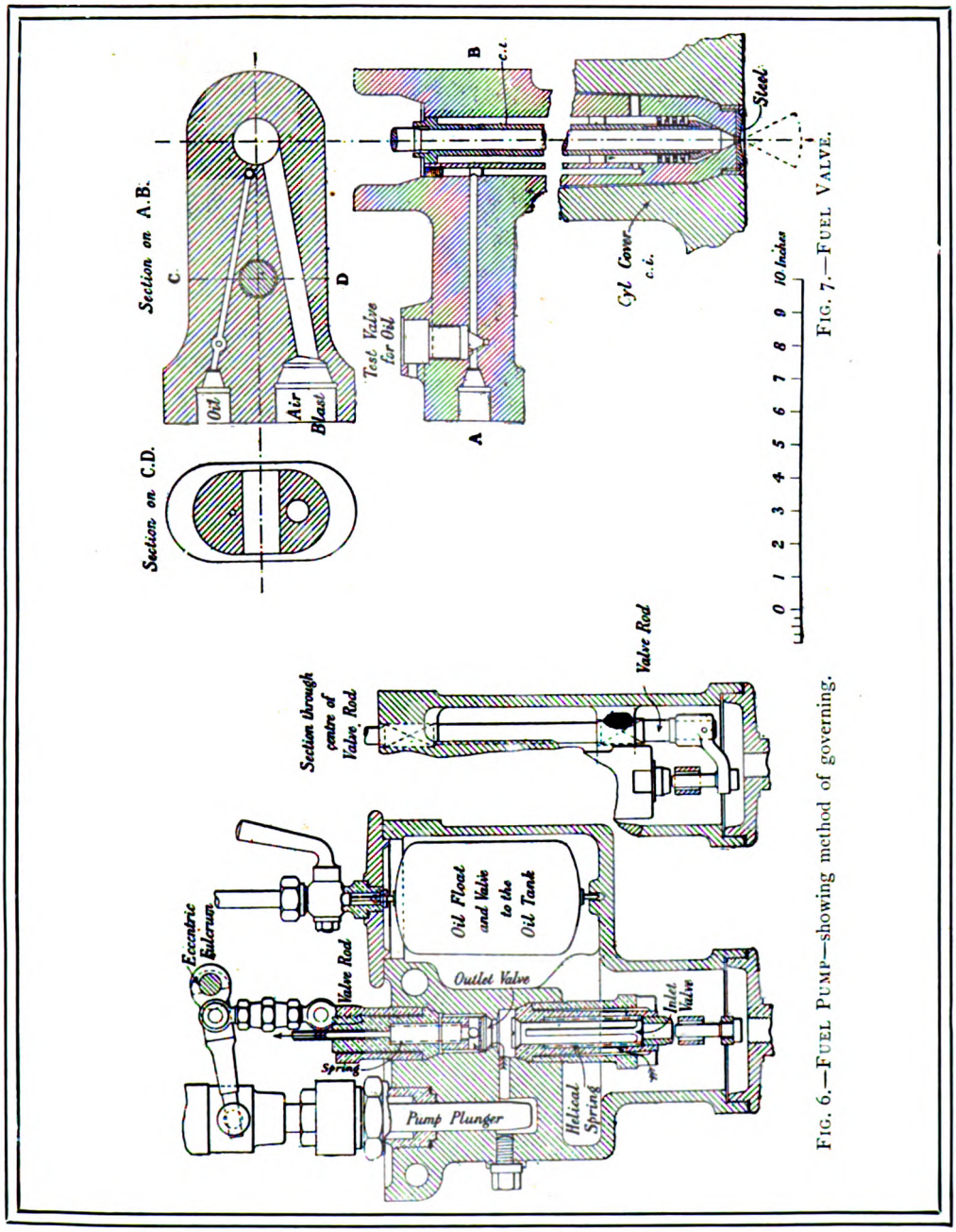

FIG. 7.—FUEL VALVE.

FIG. 6.—FUEL PUMP—showing method of governing.

further from the centre than those in the second. To the bottom of the valve is fastened the flame plate—a steel disc, with a small circular hole in the middle, and sides sloping away as shown in Fig. 8. The petroleum passage is drilled down the valve casing, and enters the interior just above the top ring. A pipe also connects the interior of the valve with the blast air reservoir.

The blast pressure (of say 750 lbs. per square inch) is always turned on when the engine is running, and the petroleum passage is full of petroleum. At the end of the suction stroke of the engine, the petroleum pump delivers a charge, varying in quantity

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according to the load. The same quantity is forced out of the passage, and falls on to the first ring. It cannot leak down the side of the casing, as the rings are accurately fitted. It therefore runs into the holes of the first one or two rings, and remains there by capillary attraction. This is the condition at the end of the compression stroke of the engine.

When the needle is lifted, the difference in pressure of the blast and the compression in the cylinder (in this case 250 lbs. per square inch) causes a rush of air to take place. The petroleum is dashed through the zig-zag holes, being mixed with the blast air in the process. Then, pulverised almost to a vapour, it passes through the orifice, is spread out radially in all directions by the flame plate, and is burnt. To prevent the holes getting clogged up, an air blast follows the petroleum each time.

Fuel Control.

The petroleum pump plunger has a constant stroke, and is driven off the end of the cam shaft. A passage connects the barrel to ordinary inlet and delivery valves closed by springs. Petroleum runs into the pump, by gravity, from large filtering cans, and is kept at a constant level in the pump by means of a float valve. A pipe leads from the delivery valve of the pump to the fuel valve of the engine.

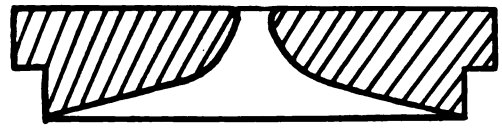

Fig. 8.—Flame Plate.

Above the pump is an excentric fulcrum which is made to rise or fall according as the governor goes up or down. Turning on this fulcrum is a cross-bar, working in a slot in the plunger head. The cross-bar, therefore, describes an arc of a circle about some centre fixed by the governor.

From a point on this cross-bar hangs a rod, going right through the pump into the oil reservoir at the bottom. This rod terminates in a cross-piece in the same plane as the inlet valve.

This rod is such a length that—

1. *When the governor is right down* the inlet valve is not interfered with at any part of the stroke. In this case, on the upstroke of the plunger, oil is drawn into the barrel through the inlet valve. On the downstroke the inlet valve is closed by its spring, and the full quantity of oil is forced through the delivery valve to the fuel valve.

2. *When the governor is half-way up* the fulcrum is raised, and the cross piece moves between two points higher up. During the first half of the upstroke, the inlet valve is opened by suction. During the second half of the upstroke, it is lifted mechanically by the cross piece. At the end of the stroke the barrel is full of oil; but on the first half of the down stroke the inlet valve is also held open by the cross piece, and half the petroleum leaks back into the reservoir. At half stroke the cross piece releases the inlet valve, which then closes by its spring. The delivery valve is then forced open, and the remaining half of the petroleum pumped to the fuel valve.

3. *When the governor is right up* the fulcrum will be in its higher position and the cross piece will move between two points such that the inlet valve is held open nearly the whole time, only enough petroleum being delivered to the fuel valve to keep the engine running at its proper speed at no load.

Oil Consumption and Working Cost.

The oil consumption varies according to size between 0·4 and 0·5 lb. per b.h.p. hour.

Mr. Ade Clark, in his trials on a twin-cylinder 160-h.p. engine at Ghent, on the 7th March, 1903, found the oil consumption at normal load to be 0·333 lb. per i.h.p. hour, and 0·408 lb. per brake h.p. hour: corresponding to thermal efficiencies of 39·25 per cent. and 32·3 per cent. respectively. This engine was running on Texas Liquid Fuel in its natural state, having a calorific value of 19,300 B. Th. units per lb. and costing 45*s.* per ton.

The cost of fuel, therefore, works out at 0·0984*d.* per b.h.p. hour.

When running at small loads, the increase in the oil consumption per b.h.p. hour is only due to the engine friction remaining constant; in fact, the consumption per i.h.p. hour is rather less than at full load, as an isothermal combustion is more nearly attained. The above engine running at $\frac{3}{8}$ load actually gave a thermal efficiency of 41·5 per cent. on the indicated h.p., which is probably the finest result ever obtained from a heat engine.

The Total Cost of Working.

The author knows of a twin-cylinder 30-h.p. engine, direct coupled to a dynamo in the sheds of the Greenock electric tramways, running for 0·66*d.* per unit. This figure includes the interest and depreciation of the land, buildings and plant, repairs and maintenance, fuel, oil, water and wages. For a larger engine it would be even less.

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CATALYSIS.

PART II.

By T. SLATER PRICE, D.Sc., Ph.D., Head of the Chemical Department, Birmingham Municipal Technical School.

PERHAPS the most important example of the use of a catalyst is in the manufacture of sulphuric acid, whether it be made by the "lead chamber" method or by the modern contact catalytic method. In the former process the combination between sulphur dioxide and oxygen, to form the trioxide of sulphur, is brought about by the aid of oxides of nitrogen. In the latter case the mixed gases are passed over platinised asbestos heated up to a certain definite temperature; the platinum acts as catalyst, by which means the combination is brought about. The reactions which take place in the old process are not by any means understood: in all probability they are very complicated. They will be referred to when discussing the various theories of catalysis. In the latter case we may perhaps get an idea of the mechanism of the process by reference to another catalytic reaction which has been investigated very fully, *viz.*, the combination of hydrogen and oxygen under the influence of platinum, whether in the form of sheet metal, platinum black, or colloidal platinum. This has been very fully investigated by Bodenstein. He measured the velocity of the formation of water from "Knallgas" (a mixture of hydrogen and oxygen in the proportions necessary for the formation of water), or Knallgas mixed with an excess of either of the components, under the catalytic influence of a platinum surface which is kept cool by a circulating current of water. When the platinum surface is quite clean and pure, the reaction proceeds at the ordinary temperature with a velocity which can readily be measured. From the results obtained when the water formed is allowed to condense on the surface of the platinum, the author concludes that the process really measured is the velocity of solution of the oxygen (in exceptional cases that of the hydrogen) by the layer of water on the surface of the platinum, the union of the gases taking place at, or in, the surface of the platinum with infinite velocity. The velocity of solution of the oxygen is less than that of the hydrogen, and thus governs the velocity of the reaction. Thus the chemical reaction, as influenced by the platinum, takes place with infinite velocity, and measurements of the velocity of reaction do not really tell us very much about the way in which the platinum acts. If the platinum is kept warmer than its surroundings it remains dry during the course of the reaction. The velocity of the reaction is then very much increased, and the results are best explained by the assumption that the velocity really measured is that of the solution of the oxygen in the platinum. These results are supported by the fact that the platinum can readily be "poisoned." If it is dipped into a dilute solution of iodine, its catalytic power is very much reduced, with the result that the combination of the hydrogen and oxygen does not take place with infinite velocity, and this affects the results obtained in a manner which can be theoretically predicted. This "poisoning" of the platinum is a very common phenomenon, and can readily be brought about by a number of different substances, among which are arsenic, hydrocyanic acid (prussic acid), sulphuretted hydrogen, etc.: it is very important, as it plays an important part in the manufacture of sulphuric acid by the contact method. However, in the case of non-homogeneous mixtures it is somewhat difficult to make quantitative measurements of the effect, but this can readily be done with colloidal solutions of platinum. The treatment of this special case would occupy too much space, however, and must be reserved for a future time.

What holds good for the combination of hydrogen and oxygen under the influence of platinum, will probably also hold in the case of the reaction between sulphur dioxide and oxygen; the chemical reaction really takes place in the surface of the platinum. This was held to be the case before the experiments of Bodenstein were made, but there was no very definite experimental evidence in support of the view. This, of course, does not do away with the difficulty of explaining why the platinum causes the reaction to proceed with such an increased velocity; that question remains unanswered at present.

It will be worth while to study this contact

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process a little more in detail, as it presents many points of interest and of great practical importance. It is only recently that the process has become commercially successful, although this method of making sulphur trioxide has been known for a very long time. The chief difficulties in the way of successful working were the gradual destruction of the catalytic power of the platinum, and also the regulation of the temperature in the contact part of the plant. These difficulties were only overcome after long and tedious research on the part of the chemists at the *Badische Anilin und Soda Fabrik* in Germany. The gradual destruction of the catalytic power of the platinum was found to be due to impurities in the gases from the pyrites burners: these impurities gradually "poison" the platinum. It was found that arsenic was the most harmful of these impurities; when the arsenic is allowed to remain in the burner-gases it gradually accumulates in the platinum, and 1 to 2 per cent. of this impurity completely destroys the catalytic action. Other substances, such as mercury, were also found to be very harmful. Since the purification of platinised asbestos which has been poisoned in this way would be a very costly matter, and also the gradual deterioration of the platinum would affect the working of the process, it is necessary to completely purify the burner-gases before they arrive at the contact apparatus. The chief difficulty is the removal of the last traces of the impurities: this is especially the case with arsenic, which is found to be present both in the fog of sulphur vapour distilling from the burners, and also in the sulphur trioxide fog which is formed, together with the sulphur dioxide, during the roasting. The thorough condensation of this latter fog is a very difficult operation, but it is absolutely necessary if all the arsenic is to be got rid of. The hot gases, as soon as they leave the burners, are treated with a jet of steam or air. This effects the combustion of the sulphur present, and at the same time the steam dilutes the acid, so that it does not attack the lead pipes, and also precipitates the solid impurities in the form of a mud. The gases are then passed through a flue, and then through a system of cooling pipes, in which the complete precipitation of the sulphuric acid and solid impurities takes place. It is found that the condensation of the sulphuric acid takes place best when the gases are cooled down slowly. The coolers in which the sulphuric acid is condensed must not consist of iron, otherwise hydrogen is liberated by the action of the acid, and this forms arseniuretted hydrogen from the arsenic contained in the sulphuric acid fog, which passes on to the contact apparatus and poisons the platinum. The gases are finally washed to remove the remaining impurities, and dried by passing through concentrated sulphuric acid.

The reaction between sulphur dioxide and oxygen is an exothermic one, being accompanied by the evolution of 22,600 calories. It follows that the temperature of the contact mass will finally become very high, unless steps are taken to keep it down. At first sight it would seem to be an advantage to let the temperature become as high as possible, since the velocity of a chemical reaction is increased by a rise in temperature. This, however, depends on whether the reaction is complete, or whether it is a reversible one. In the present case the reaction is reversible, a definite equilibrium being attained; or, in other words, besides the formation of sulphur trioxide from oxygen and sulphur dioxide, there is the decomposition of the sulphur trioxide formed into oxygen and sulphur dioxide. Both these reactions go on simultaneously, but their relative proportions depend on the temperature. It is found that below 200° C. there is practically no reaction, but that at this temperature the reaction takes place slowly. As the temperature rises, the formation of sulphur trioxide becomes more marked, until at 450° C. it reaches a maximum; above this temperature the conversion of the mixed gases into the trioxide becomes less marked, since the reverse reaction, the decomposition of the sulphur trioxide becomes very evident, until at 900°—1000° C. the reverse reaction is the only one which takes place, *i.e.*, there is no formation of the trioxide. It follows, therefore, that for the best results to be obtained the temperature of the contact apparatus must be kept somewhere about 450° C.; it is also advisable to heat the gases to a temperature of 250°—300° C. before they enter the converter. In order to carry out both processes at the same time, *i.e.*, keep the temperature of the converter approximately constant, and preheat the gases, the principle of "counter currents" is used. The cooled and purified gases from the burners are passed along the outside of pipes containing the contact mass, before entering these to travel in the opposite direction. The burner gases thus cool the reacting gases and the contact mass, and at the same time they are heated up to the

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necessary temperature for the reaction to proceed most favourably.

The regulation of the temperature of the contact apparatus has been attained in other ways which cannot be entered into here. The question of the contact material to be employed is of great importance, since platinised asbestos is not the only one. Asbestos is a very good carrier for the platinum, because the surface offered per unit weight is so very large; it has, however, the disadvantage of packing together under a comparatively small pressure, unless great precautions are taken in the arrangement of the contact mass. This has led to the use, or suggested use, of other carriers in the place of asbestos; among these are soluble salts, which must be such that they remain unchanged by the action taking place between the gases in the converter. In the present case a sulphate could be used. The mode of preparation is to form a solution of the salt and of platinic chloride, and evaporate the whole to dryness, breaking up the crusts formed into pieces of uniform granular size. The separation of the metallic platinum into a very fine state of subdivision takes place on heating the contact mass when the process is started. In some cases the contact mass is made very porous by arranging that a gas, such as carbon dioxide or hydrochloric acid, is evolved during the drying of the mass.

Since platinum is so dear, it would be very advantageous if it could be replaced by some other catalyst. Among such catalysts are the oxides of copper, iron, and chromium. The *Verein Chemischer Fabriken* use ferric oxide at their works at Mannheim. It is not necessary to purify the burner gases before they are admitted to the contact mass, since it is found that the oxide abstracts most of the arsenic to form a non-volatile compound, with the result that a fairly pure product is obtained. The oxide gradually loses its catalytic power as the percentage of arsenic increases, but it can readily be replaced at a comparatively small cost.

One very interesting point in connection with the contact method of manufacture of oil of vitriol is the method of absorption of the sulphur trioxide. Although this substance has such a very great affinity for water, it is found that the gas can be passed through water, or a dilute solution of sulphuric acid, without being completely absorbed. If, however, it is passed into 97–98% sulphuric acid, it is completely absorbed.

I have dealt with the manufacture of sulphuric acid, according to the most modern method, in some detail, because of its great technical importance. It illustrates very well the difficulties which have to be overcome in order to make an industrial process successful. These difficulties were only overcome after protracted and patient research on the part of the chemists at the *Badische Anilin Fabrik*, chemists who possessed not only a practical knowledge, but also a thorough acquaintance with theoretical chemistry, especially the branch known as physical chemistry.

Fuller details and references can be found in a paper by Conroy in the *Journal of the Society of Chemical Industry* for March, 1902.

Among other contact catalytic processes which may be mentioned is the manufacture of chlorine from gaseous hydrochloric acid and air by the Deacon process, the catalyst used being a salt of copper. Also the manufacture of sulphur in a Claus kiln by the partial oxidation of sulphuretted hydrogen by means of air, under the catalytic action of oxide of iron.

Another interesting reaction of a totally different kind is due to the addition of a soluble chromate or bichromate to the electrolyte in the preparation of chlorates, bromates, and iodates, by the electrolysis of solutions of the haloid salts.* Thus, it has been shown by Müller that, in the electrolysis of a 30 per cent. solution of sodium chloride the current efficiency can be increased from 32·8 per cent. to 69·6 per cent. by the addition of 0·18 per cent. of potassium chromate; in another instance the efficiency was increased from 65·7 to 88 per cent.

Considering the case of the chlorates, it is possible to get an idea of the mechanism of the reaction. The first step in the process is the formation of hypochlorite of sodium, the chlorine evolved at the anode acting on the caustic soda formed at the cathode. This hypochlorite is then transformed into chlorate. When the hypochlorite formed comes in contact with the cathode it acts as a depolariser, and is in consequence reduced, thus lowering the yield of chlorate. Müller found that, when the chromate was added to the solution, a deposit containing chromium was formed on the surface of the cathode, which deposit is not metallic, but contains oxygen. This deposit then acts as an ideal diaphragm, since it is not permeable to the hypochlorite, and prevents it from coming in

* "Electro-Chemical and Electro-Metallurgical Industries," by J. B. C. Kershaw, TECHNICS, No. 6, Vol. I. (June, 1904), p. 553.

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contact with the electrode and acting as a depolariser.

It is also known that, in the production of periodates by electrolytic oxidation, the addition of sulphates and chlorates to the electrolyte bring about an increased efficiency; but so far no satisfactory explanation has been given.

Acids form one of the most important classes of catalytic agents. There is an immense number of reactions which are affected by the presence of acids, or rather, of what is common to all acids—hydrogen ions. Thus, if cane sugar is boiled up with pure water it is not affected, or affected only very slightly; but if an acid is added, the sugar is quickly inverted, *i.e.*, it is changed into a mixture of dextrose and lævulose, one molecule of the sugar taking up one molecule of water with the formation of a molecule of each of the above-mentioned compounds. The acid does not enter into the reaction equation at all. Investigations have shown that the action of the acid is strictly quantitative, the velocity of the inversion being proportional to the number of hydrogen ions contained in the solution of the acid used. Similar results are obtained in what is known as the catalysis of methyl acetate. This compound is only very slowly decomposed by pure water into methyl alcohol and acetic acid; in the presence of hydrogen ions, however, the velocity is very much increased, and is directly proportional to the concentration of these ions. Since the acid does not enter into the reaction equation, it follows that comparatively small quantities of acid are able to cause reaction to take place between large quantities of the reacting substances. The reactions affected in this way are very numerous, some of them being important from a manufacturing point of view. It is only necessary to refer to the manufacture of glucose by the catalytic action of sulphuric acid on starch, in order to call attention to the importance of this branch of catalysis.

An interesting example of the influence of hydrogen ions in an inorganic reaction is the decomposition of sodium thiosulphate by means of an acid. It is well known that when an acid, such as hydrochloric acid, is added to a solution of thiosulphate, there is not an immediate evolution of sulphur dioxide and precipitation of sulphur; this only takes place after waiting for a short time. It has been found that the time which elapses before the precipitation of the sulphur, depends on the concentration of the hydrogen ions; if hydrochloric acid is added the precipitation takes place much sooner than when an equivalent solution of acetic acid is added. The time elapsing before precipitation takes place is always the same within one or two seconds, when the same acid is used in different experiments, providing that the same concentrations of solutions are taken in all cases.

Theories of Catalysis.—This, at present, is the most unsatisfactory aspect of the study of catalysis. When one considers, however, the enormous number of reactions which are influenced catalytically, and the great diversity of these reactions, it is obvious that it will be extremely difficult to find a theory which will apply in all cases. Even if we group the various catalytic reactions into a number of divisions, it will be difficult to find an explanation which will hold for the different reactions in each division.

The first attempt to formulate a theory was made by Liebig. He supposed that the catalyst is a very active substance, and by its presence causes similar chemical activity in the reaction mixture to which it is added. He illustrated his meaning by giving, as an analogy, the fact that one burning substance will set other substances burning. The example was not well chosen, however, since it is not necessary to have one substance *burning* in order to start others; it is simply a question of raising the temperature to the ignition point. He then slightly modified the theory by the hypothesis of "molecular vibrations, or swingings." The atoms of the catalyst are supposed to be in a state of molecular vibration, and when added to the reaction mixture these vibrations are imparted to the reacting substances, with the result that chemical reaction is either induced or accelerated.

This theory possesses the disadvantage of being neither capable of proof nor of disproof. Also, it is not a useful theory in the sense that it does not point out directions for research; as a matter of fact, it has led to no increase in our knowledge of chemical reactions.

The theory which has found the most favour is that of "intermediate reactions." This is best illustrated by reference to the reaction to which it was first applied, *i.e.*, the manufacture of sulphuric acid by the ordinary lead chamber process. Sulphur dioxide is not oxidised directly by means of the air, but indirectly by means of the oxides of nitrogen. Nitric oxide takes up oxygen from the air with the formation of nitrogen peroxide; this substance then oxidises the sulphur dioxide to sulphur trioxide, and is at the same time

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reduced to nitric oxide. The same reactions take place again with the formation of more trioxide, and so on.

In connection with this theory, there are several important points to notice. It is not enough to assume that such intermediate reactions take place, but one must be actually able to prove their existence. In some cases the products which would be formed in the intermediate reactions formulated have been isolated, and this has been looked upon as a proof that the reactions explain the catalytic effect. This is not necessarily the case, since the products isolated may be due to side reactions, and not connected with the main reaction at all. It is also necessary to prove that the assumed intermediate reactions take place with a velocity which is greater than that of the direct action, since one must assume that a reaction will always proceed by the quickest route.

A great stumbling-block in connection with this theory was the cases of so-called "negative catalysis." The velocity of oxidation of sodium sulphite, when air is bubbled through the solution, can readily be measured. Bigelow found that the velocity was very much diminished by the presence of traces of such substances as glycerine, alcohol, mannite, etc.: this was explained (?) by assuming that these substances acted as negative catalysts. There is, however, another possible explanation, *viz.*: that the reaction is really brought about by the presence of an accelerating catalyst, but the action of this latter is affected by the addition of glycerine, etc. This has recently been shown to be the case by Titoff. He found that the presence of minute quantities of iron or of copper salts has an enormous influence on the velocity of oxidation. Thus a solution containing 63 grams of copper in one thousand million litres of water has an appreciable effect on the velocity of oxidation: this is very well shown by the following experiment:—

Pure water was allowed to flow over a small, thin, clean copper strip: it was found that the water so obtained had dissolved enough copper to increase the velocity of oxidation by 80 per cent. Since ordinary distilled water is generally prepared in copper vessels, which are supposed to be well tinned inside, one can readily understand that if the tinning is deficient at any part, the water obtained will contain copper.

In this particular case of a negative catalyst, we have the superposition of two reactions, the so-called negative catalyst destroying the action of the positive catalyst, and thus apparently directly retarding the main reaction. It is probable that similar results will be obtained for all cases of negative catalysis, and thus this objection to the theory of intermediate reactions will no longer be valid.

In recent years the evidence in favour of intermediate reactions has been accumulating. Thus Brode has investigated the oxidation of thiosulphate to tetrathionate by means of hydrogen peroxide, using iodine as a catalyst; the reaction proceeds very slowly in the absence of iodine, but in its presence it takes place readily. Brode has shown that the two intermediate reactions involved proceed with velocities which will account for the observed velocity of the main reaction.

Another kind of reaction which will probably have a bearing on the explanation of catalytic processes is known as "chemical induction." To take an example:—

1. Bromic acid has practically no oxidising action on arsenious acid.

2. Sulphurous acid is almost instantaneously oxidised by bromic acid.

3. If sulphurous acid is added to a mixture of bromic and arsenious acids, not only is the sulphurous acid oxidised, but part of the arsenious acid as well. Thus the reaction taking place between the bromic acid and the sulphurous acid "induces" a reaction between the bromic and arsenious acids. Reactions of this kind are now known to be very common; formerly they were completely overlooked, with the result that some researches which have been carried out have been invalidated. The investigation of such processes is a very difficult one, however, especially as far as the mathematical treatment is concerned. Among such induced reactions it is possible that we may class the mutual effects which two catalysts often have on each other, as in the case of the action of copper and iron salts in the catalytic reactions already referred to.

It must not be supposed that all cases of catalysis will be explained on the assumption of intermediate reactions. We have already considered an example due to another cause, in the case of the influence of chromates on the electrolytic formation of chlorates, etc. Another example which might be cited is the solution of pure and impure zinc in dilute acids; as is well known, the pure metal dissolves only very slowly, but the impure substance dissolves rapidly. It has been conclusively shown in the last few years that the explanation is an electro-chemical one, but that question cannot be entered into here.

Perhaps it will be as well to refer to the

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various theories with regard to the production of sulphuric acid by means of the lead chamber process. The simplest possible interpretation of the process has already been given; but in all probability the reactions are very complicated, since there are quite a number of important points which occur in the manufacture which are not explained by the above theory. Thus, it is found that even in the first chamber the acid which is formed contains a large percentage of nitrosulphonic acid, $SO_2OH.NO_2$, and this probably plays a part in the reaction which takes place. According to Lunge, the following equations represent the chief reactions :—

$$2SO_2 + NO_2 + NO + O_2 + H_2O = 2SO_2OH.NO_2.$$

$$2SO_2OH.NO_2 + H_2O = 2H_2SO_4 + NO + NO_2.$$

$$2SO_2OH.NO_2 + SO_2 + 2H_2O = 3H_2SO_4 + 2NO.$$

The first two equations represent the main reactions, while the third explains the occurrence of a large amount of nitric oxide in the first chamber, and also represents the process which goes on in the Glover tower. Besides these equations, Lunge gives a number of subsidiary ones, such as the following :—

$$SO_2 + NO_2 + H_2O = H_2SO_4 + NO.$$

$$SO_2 + HNO_3 = SO_2OH.NO_2.$$

$$2SO_2 + 2NO_2 + O + H_2O = 2SO_2OH.NO_2.$$

These equations all represent possible reactions, but it is an exceedingly difficult matter to submit them to proof. It is not enough to show that such reactions can take place with the formation of sulphuric acid, thus giving a qualitative proof; but quantitative measurements must be made, to see if they agree with the results ordinarily obtained. It is here that the chief difficulty comes in, since the reactions take place with a very great velocity, so that they are difficult to measure; and moreover, perfectly satisfactory methods of analysis have not, so far, been devised.

The theory of Lunge does not account for the fact that nitrous oxide, nitrogen, and traces of ammonia are found in the chamber gases at times; nor does it explain why the concentration of the acid in the chambers only varies between 55 and 65 per cent., and that the denitration of the chamber acid by dilution with hot or cold water, or steam, is very incomplete. Furthermore, an explanation is wanting of the fact that a given zone in the Glover tower will denitrate 200 times as much acid as an equal space in the chambers.

According to this theory, the hydrolysis of the nitrosulphonic acid is the most productive of the reactions, but from what has been said this cannot be the case. If it were so, only a relatively small quantity of acid would be produced in the Glover tower, since the dilution of the nitrosulphonic acid is too small for hydrolysis to take place to any extent, as has been shown by the most recent experiments. Furthermore, it has been shown that the joint action of sulphur dioxide and evaporation gives the most advantageous results. Similar remarks hold for the process which takes place in the chambers. The alterations in the concentration of the water are relatively small; one can, however, agree with the theory of hydrolysis of nitrosulphonic acid on the understanding that it is not the solid compound, but that which is dissolved in strong sulphuric acid, which is hydrolysed by diluter acid.

One will then naturally ask, where does the acid come from, in which the nitrosulphonic acid is at first dissolved; and how is the latter compound formed? Experiments have shown that nitrosulphonic acid is immediately formed from SO_2, O, NO or NO_2 and a little water; in the presence of more water a solution of nitrosulphonic acid in sulphuric acid is obtained.

The latest theory assumes the existence of an intermediate "nitric oxide disulphonic acid," $NO(SO_2OH)_2$, which compound, however, has not been shown to occur in the course of the manufacture. The equations are as follows :—

$$2NO_2.SO_2.OH + 3SO_2 + 2H_2O = 2NO(SO_2OH)_2 + H_2SO_4.$$

$$NO(SO_2OH)_2 + 2SO_2OH.NO_2 + 2H_2O = 3NO + 4H_2SO_4$$

$$2NO + O_2 = 2NO_2.$$

Since I have referred to the catalytic action of manganese dioxide on the evolution of oxygen from potassium chlorate, it will perhaps be of interest to mention that the theory of intermediate reactions has been put forward in this case also; the manganese dioxide going through a cycle of changes in which it is transformed to permanganate and manganate of potassium. At the same time chlorine occurs in the free state during the progress of reaction. The equations supposed to represent these changes will be found in most of the text-books on chemistry.

It is quite possible that these reactions may occur, and it is an undoubted fact that chlorine is formed in small quantities during the reaction; it is, however, doubtful if the catalytic

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action of the manganese dioxide can be explained in this manner. Other oxides, such as ferric oxide, act in a similar way, and even dry sand will slightly increase the velocity of evolution of oxygen. It is possible, as suggested by Ostwald, that it is simply a supersaturation phenomenon; the oxygen remains in supersaturated solution in the melt of chloride and chlorate, and the addition of the catalysts in the form of a powder, offers nuclei for the formation of bubbles of oxygen, since the powders will always have air clinging to them. The evidence for this, however, is not by any means conclusive.

From what has been said the reader will see the infinite possibilities of the subject of catalysis, and how very little we know about it. It is possible that in the next few years some theory may be proposed, which will not only account for observed facts, but, as should be the case with all theories, enable us to predict new cases of catalysis, and thus lead on to the study and application of hitherto undreamed-of branches of chemistry.

COLONIAL COTTON.

By J. H. DAWSON.

COLONIAL cotton is the hope of the British textile trades, and thus the colonies capable of producing cotton are acquiring a particular interest for cotton spinners. It therefore behoves these to obtain a thorough grasp of the various conditions under which cotton is raised at present, and also to search out the possible fields of extension, the climatic and natural surroundings of such places, together with all the details attendant upon this interesting question. The cotton belt or zone extends from 45 degrees north to 35 degrees south of the equator. Lying within this zone are many countries where cotton could be grown, although it is not grown at present; together with many other places where it would be almost impossible to grow cotton with success, even if anyone were foolish enough to attempt it.

Having obtained a list of places lying within the cotton zone, to which geographers ascribe climatic conditions, soil, etc., suited to cotton growing, the question arises as to whether it would "pay" to raise cotton in these places. This, of course, is another phase of the question, but nevertheless it is the one upon which the future of the movement will depend. At present, employers and employed are vieing with each other in subscribing funds to give the venture a start, but it will eventually be left to itself, to stand or fall according to its merits.

FIG. 1.—IN A COTTON FIELD.

The situation of the proposed new field must be considered with regard to its chances of being well supplied with manual labour capable of being trained to the efficiency (or somewhere near it) of that to be found in the existing plantations. The plentiful supply of animal power, for ploughing, plantation hauling, etc., is another very important factor. The healthiness or otherwise of the district must be considered, as it will influence the importation of overseers, etc., who, for a commencement, would have to be experts from other parts of the world. The distance of the proposed fields from the railway, the

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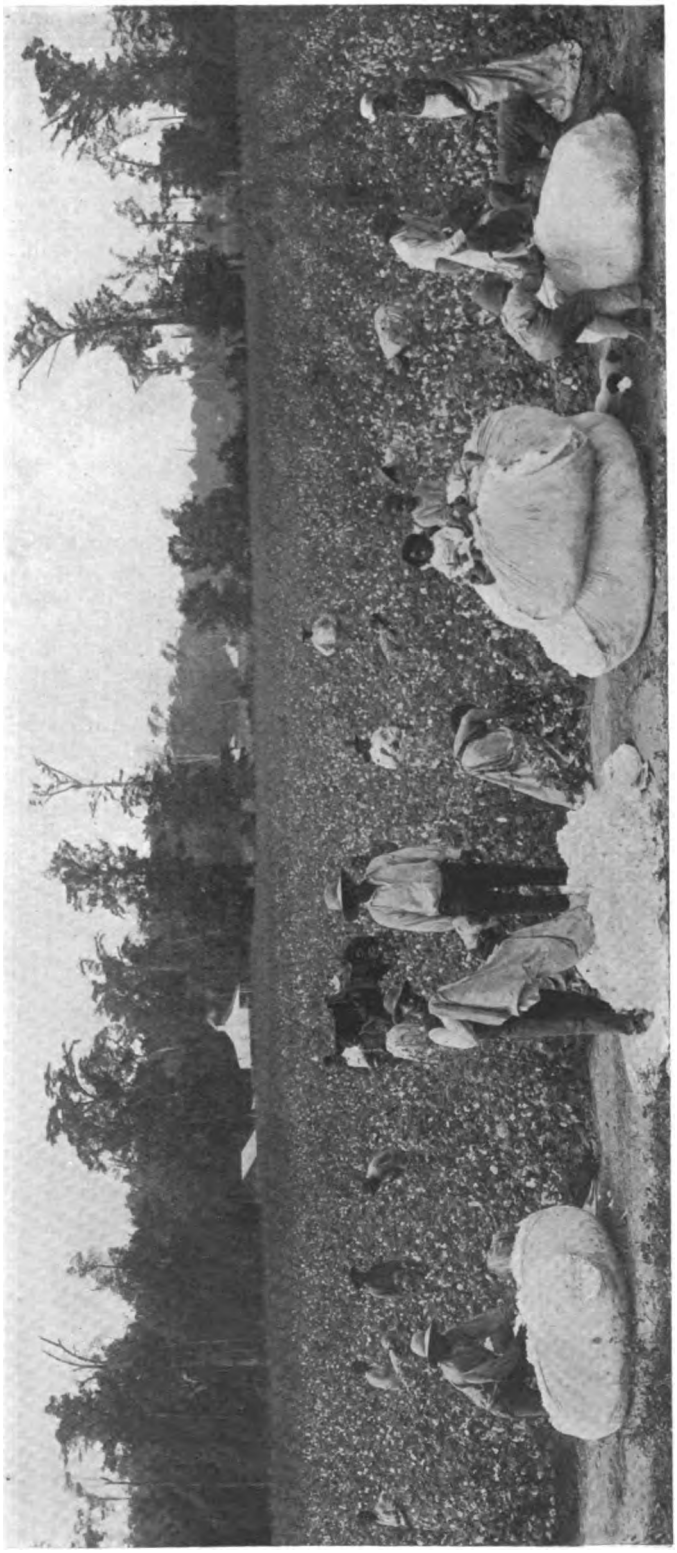

FIG. 2. COTTON PICKING.

condition of the roads (if any), and the facilities for berthing large vessels at the railway terminus, are points perhaps as important as any. Taken altogether, then, it will be seen that the difficulty does not lie in finding land where it is possible to grow cotton, but in finding spots that have, or could acquire with little trouble and expense, the facilities for growing, picking, ginning, baleing, and exporting the cotton essential to a successful competition with the present monopoly.

To start a cotton plantation in some places and work it efficiently would be a far more arduous undertaking than appears at first sight. Having found suitable land, which must be of a light soil, with a good subsoil of a stiffish nature to arrest and reserve the moisture, it will need preparing. It is the custom in some districts to plough the land in furrows, leaving passages wide enough for the pickers to pass through during the picking season (Fig. 2). In other districts the seeds are planted, by machine, about 3 or 4 inches apart, and when the seedlings come up the healthiest are selected, and the others, together with weeds, are "hoed" down; the probable height of the plant when mature determining the width of the spaces hoed between the plants. In some of the uplands, where the plant

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only attains a height of about 2 feet, the spaces would require to be much less than in Memphis, say, where it grows to a height of 5 or 6 feet (Fig. 4). In both cases, however, machines must be operated, requiring oxen, mules, or horses, whichever are available. Systems of drainage for wet weather, and of irrigation for dry weather are also preferable, although these may be dispensed with. The land having been prepared for planting the seed, it becomes necessary to determine the particular seed to plant. The best time of planting would have to be found by experiment, or else deduced from data relating to the agriculture of the district. Of seeds, more ought to be known than is known; or perhaps I should say, that greater advantage ought to be taken of our present knowledge than is generally taken. It is a fact that many experiments in cotton growing have failed, simply because the planters did not obtain the seeds best suited to the district.

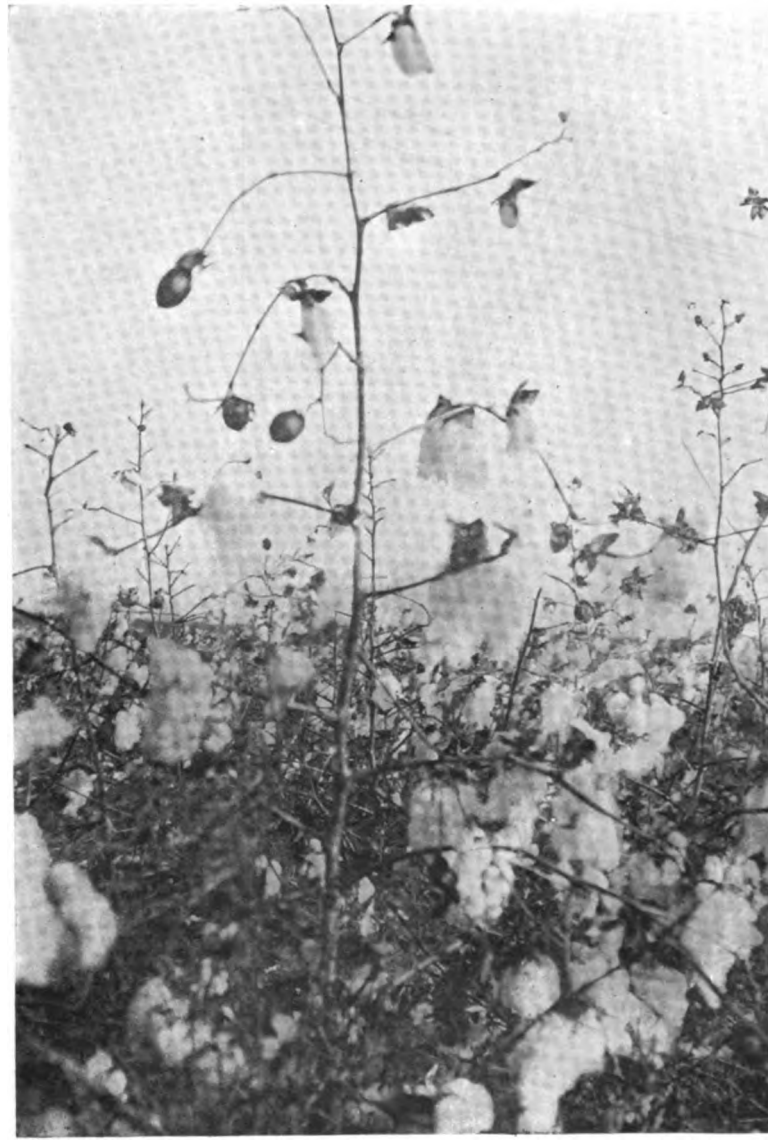

FIG. 3.—THE COTTON PLANT AFTER THE BOLL HAS OPENED.

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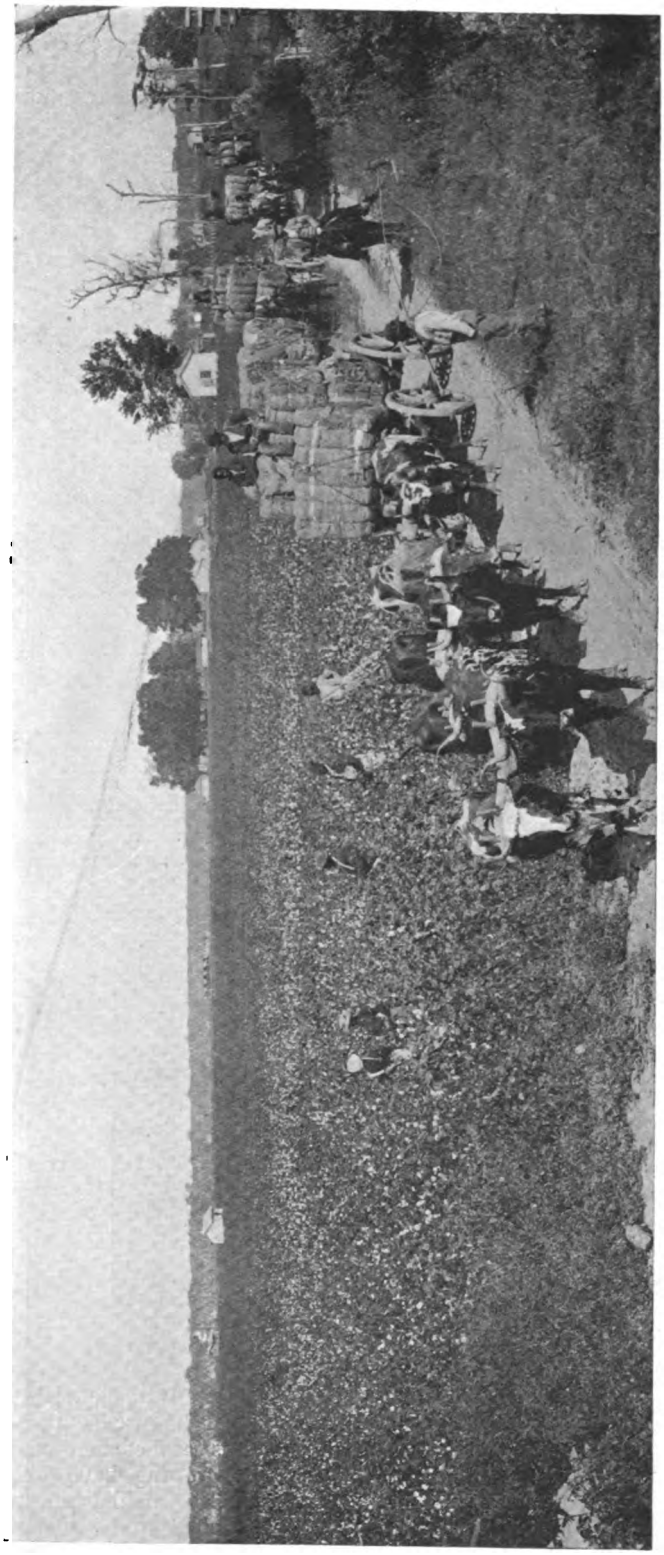

FIG. 4.—COTTON FIELD, MEMPHIS.

In some cases, even when the best seeds were used in the first instance, the quality was allowed to deteriorate, through the negligence of those in charge. They omitted to obtain periodical supplies of new seed, in order to keep up the strength and fruiting power of the plants, and year after year planted seeds obtained from the previous crop, even when these seeds were only of a questionable quality. This is a fatal mistake; and, in passing, I may say it is not confined to recruits, but is sometimes made by old and experienced planters. These latter, however, do not make the mistake through ignorance of the requirements of the case, as a new planter might; but simply through selfishness and a desire to get as much out of a crop as possible, without a serious thought of the future, or of the people who have to convert the lint into cloth. These men are in the habit of selecting the best of the seeds that the "gin" removes from the fibre, and selling them to the crushers, who extract from them the "cotton seed oil." They then plant the second-rate seed the following season: seed that would not fetch top price as an oil producer is expected to give satisfaction as a cotton producer, with the results that might have been anticipated.

After planting, sufficient care must be taken of the growing plants, during the period from the hoeing to the fruiting. All weeds and insect pests must be fought against, so that

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FIG. 5.—"CLASSING" COTTONS.

the plants are healthy and vigorous when the flowering takes place. Once the boll begins to open (Fig. 3) the climatic conditions must be depended upon to mature it, and manual labour must be called in to gather it. Picking machines have been tried, but with little success.

From the plantation to the ginnery (Fig. 6) and thence to the compress are all stages that must be seriously taken into consideration by prospective cotton growers. The "classing" of the various growths (Fig. 5) is a very important operation, which can only be successfully carried out by experts. Badly selected cottons would soon ruin the reputation of a district; and in the case of new plantations, this operation, if indifferently performed, would wreck the highest hopes of the well-wishers of the colonial cotton growing movement.

FIG. 6.—THE GINNERY.

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ROOF BEVELS.

PART II.

By RUFUS E. MARSDEN.

OWING to the enormous values attached to central positions in large towns and the natural desire to make the most of sites acquired by such heavy expenditure, the roofs of buildings in congested districts by no means exhibit a uniform regularity of plan. While the rectangular planned building is generally desirable for several reasons, including that of economy of cost, yet those less regular in plan have the obvious advantage of making the most of the available space. Therefore, this concluding paper will deal with the solution of problems afforded by roofs of irregular plan.

It is impossible in these papers to deal in detail with all possible variations of roof construction, but fortunately it is only necessary to deal with examples involving certain problems; for the principles by which bevels can be obtained for roof timbers, in roofs having only plane surfaces, are the same in all cases.

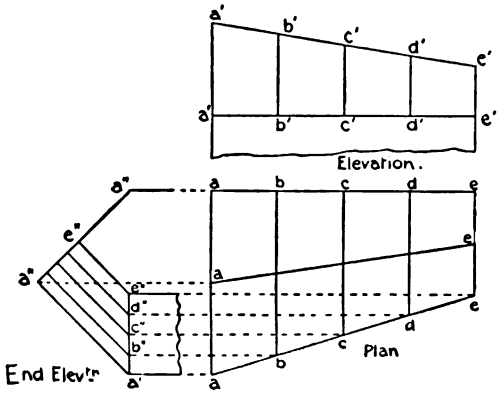

FIG. 7.

The simplest deviation from a complete rectangular plan is that shown in Fig. 7, in which the end walls are both at right angles to the front wall, while the back wall makes an angle with it. A study of the possibilities of roofing this site will ensure the consideration of some useful problems.

There are four principal methods by which the site shown could be covered with a simple roof of one span, having gable ends.

The first method, Fig. 7, is to build the back and front walls to plate level, and throw pairs of rafters across the span from back to front. So as not to render the drawing too complicated, only four such pairs of rafters are shown by *a a a*, *b b b*, etc., these being quite sufficient to explain the principles involved.

Now, as the plan widens from end to end, the height at which the pairs of rafters intersect, if all are equally inclined, also increases, as shown by the end elevation, Fig. 7.

This causes the ridge to be inclined, as shown by the elevation, looking at the back wall and towards the front one. The height of any point in one elevation can always be obtained from another elevation by measuring an equal height off the same level in both cases, as can easily be seen by looking at any object from the front and end successively. So that, given the plan and end elevation, as in this case, it is an easy thing to obtain the side elevation, by projecting up points from the plan and marking off heights above some level (in this case wall plate level) equal to the heights of the points above the same level in the end elevation. Now, it is not usual

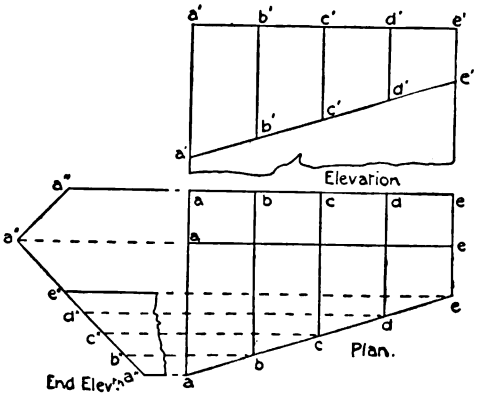

FIG. 8.

to have the ridge inclined, as in Fig. 7, so the effect of fixing the ridge level to start with must be considered. In Fig. 8, the ridge is level, as shown by *a' e'* in elevation and *a e* in plan; the rafters occupy the same position in plan as before. By drawing the

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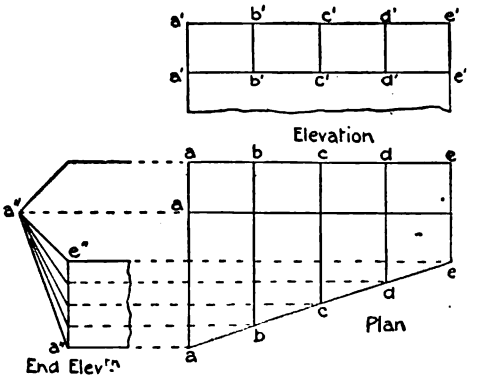

FIG. 9.

end elevation of each pair of rafters it is found that they cut the line of the back wall at points which lie at a lower level towards the wider end. This causes the eaves line of the back wall to be inclined as shown in the elevation, Fig. 8. It will be noted that had the ridge in plan been placed, not parallel to the front wall, but in the centre of the plan as in Fig. 7, then the front eaves line would also have been inclined.

Although in some particular cases, where the inclination of the eaves line is slight, and the method of construction allows, this plan of roofing an irregular site could be adopted, yet it is not usual in general practice.

A third attempt at a satisfactory solution of the problem is made by building the walls up to plate level, as in Fig 7, and fixing the ridge so as to be level from end to end. This, as shown in Fig. 9, gives rafters unequally inclined; as the span widens the rafters have less inclination. In this case, the roof is said to "wind." Although the writer knows of a roof actually constructed on this principle, yet it must be admitted that it is the worst of the three methods yet described.

If the reader has closely followed, and demonstrated to himself by the construction of rough models, what has already been attempted in solving the problem of roofing a non-parallel site, he will easily see that only when the ridge is parallel to wall plate can both ridge and eaves lines be level while the rafters are all equally inclined. So that the best possible form of simple roof to cover the irregular site shown is given in Fig. 10.

Here lines representing the ridges in plan are drawn parallel to the front and back walls. The portion of the roof lying between these ridges is occupied by a flat, and the elevation from either back or front gives a similar effect to that given by a parallel building with only one ridge.

Having thus determined what is to be done with a roof over a building having non-parallel sides, we can proceed to the example given in Fig. 11. This shows a roof with hipped ends. Once decided that a flat of the shape E F G is necessary, the next thing is to find from which point to start drawing lines F E, F G. The inclination of the sides and ends must be settled before the plans of the hips can be correctly drawn. In the example the inclination has been taken as one of 30° from all sides.

So that the method of obtaining hips under all conditions may be understood, the problem will be discussed in some detail. In Fig. 12 the plan of two pieces of moulding having an exactly similar section are shown meeting at right angles. By a close inspection of the mitre it will be seen that lines in plan representing points at the same level in sections A and B intersect on the mitre line. This is a fact well known to the practical man, for all he does to obtain the correct bevel for mitring two pieces of moulding is to draw the plans of corresponding lines of each piece in its correct position, as in Fig. 13, which shows two equally inclined surfaces intersecting at right angles; and Fig. 14, which gives similar surfaces intersecting at an obtuse angle. In Fig. 15 are shown two

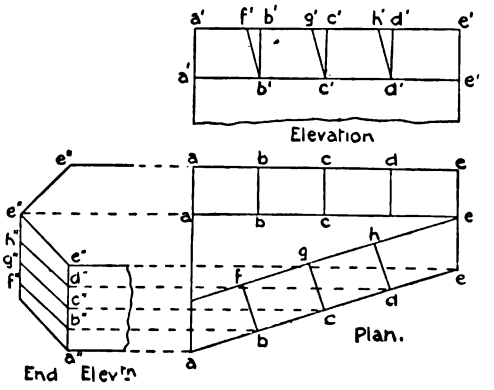

FIG. 10.

unequally inclined surfaces, A of 30°, B of 45°, meeting at right angles. In this case all that is required to find plan of intersection of surfaces is to draw plans of lines lying at the same height in both surfaces and find their points of intersection. Such lines are *a a*, *b b*, etc., and the line passing through points of intersection of these lines

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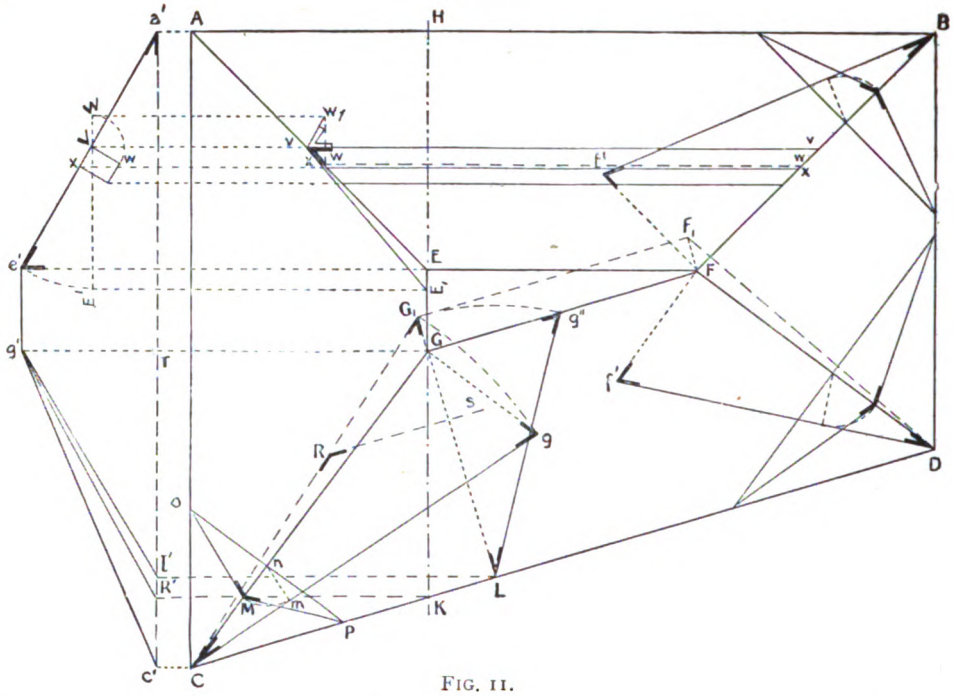

FIG. 11.

is the plan of intersection of the two inclined surfaces.

It will be noticed from the examples given (Figs. 12—14), that when the intersecting surfaces are of similar inclination, the mitre or intersecting line bisects the angle between the level lines on the surfaces. So that, in Fig. 11, to determine the plan of the hips, starting from the corners A, B C, D, in each case the angle between the lines of the wall plates must be bisected. Where the hips from D and B intersect gives the correct point from F.

Lines drawn from F parallel to A B, D C, and a line joining points in which E F, G F intersect hips A E, C G, complete plan of roof.

From the completed plan it is now an easy matter to determine the bevels for each individual member.

To arrive at the bevels for the hips it is only necessary to draw lines from their highest end at right angles to their plan, and upon these lines mark off the difference in height between the higher and lower ends of the hip. Taking the hip C G as an example, draw G g at right angles to C G, and make G g equal to the distance of G above C; this distance is obtained from the end elevation, and is equal to T g'; then the bevels for hips C G are shown at g and C, the length of the hips being C g.

The backing for the hip C G is obtained by selecting any point n on its plan, and through this point drawing O P at right angles to the hip C G in plan. Then from n draw a line n m at right angles to elevation of hip, C g, and with radius n m, centre n, rebatt the point m to M. The angle O M P is the angle for backing the rafter.

The remaining hips have been treated in a similar way. The reason for this method of procedure in finding bevels for hip rafters was fully explained in Part I., so there is no need to repeat it here.

As an example of the method of finding bevels at which to cut the boards and jack rafters for this roof, the side C G F D has been worked out.

This side has been rebatted into the plane of the wall plates so that its true shape is exposed. Using C D as a hinge, the points G and F will move in plan along the lines G G_1 and F F_1, which are at right angles to C D. The point G stops at G_1, when G_1 L is equal to the true length of the rafter G L. By projecting from the plan of this rafter on to the end elevation we do not obtain its true

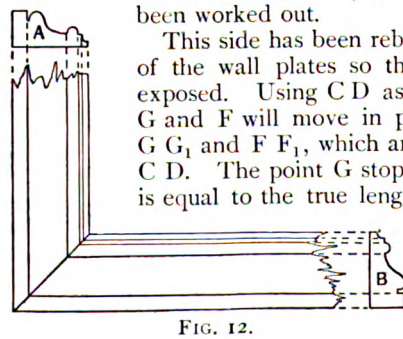

FIG. 12.

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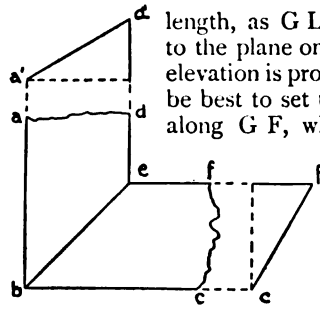

FIG. 13.

length, as G L is not parallel to the plane on which the end elevation is projected; so it will be best to set up a height G g'' along G F, which is at right angles to plan of rafter G L. G g'' is equal to the height of the end G above plate or working level. Now rebatt g'' on to the plan by taking the compasses with centre L and radius L g'', and drawing arc, g'' G_1 to cut G G_1 at G_1. Then LG_1 is the rafter G L rebatted into the horizontal plane. As all the rafters along side of roof are equally inclined, it is evident that when side is developed, that G_1 F_1 is parallel to G F, so that complete development CG_1 F_1 D is easily obtained. The top bevel for jack rafters is shown at G_1, and the bevel for boards at R. These are obtained by drawing a line at right angles and parallel to side C D, so as to meet the developed hip. As C G_1 and C g both represent the true length of hip C G, this suggests another method of getting development of side C G F D, which is to draw an arc with centre C and radius C g, so as to cut G G_1 at G_1, and join as before.

The shape of the roof across the line H K is given on end elevation by d' e' g' k', this being the shape of a roof truss necessary to support this end of the roof.

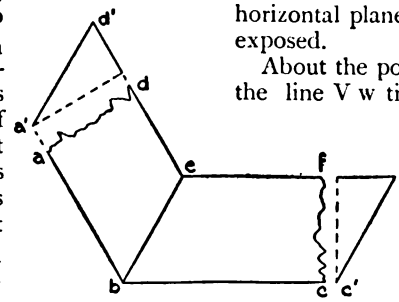

FIG. 14.

In large roofs, besides the members mentioned in Part I., we have another which requires to be cut to bevels, to be obtained from the drawing, namely, the purlin. On the end elevation, Fig. 11, a purlin is shown at X V W, and the bevels which have to be determined are those for the side, V W, and the top, X V. The plan of the mitre between side and end purlin coincides with plan of hip A E, so that v v w and v v x are the plans of the bevels of top and side respectively. To obtain their correct shape, all that has to be done is to rebatt them till they lie in a horizontal plane, when their true shape will be exposed.

About the point V in end elevation, swing the line V w till it reaches W on the horizontal line E' W. While this is being done w in plan has moved along w w_1 till it has reached w_1, a point obtained by projection from w on end elevation. Then v v w, as shown, is the side bevel for cutting the purlins.

As the top cut V x, end elevation, and v x plan coincides with hip A E, it will be plainer if, instead of merely swinging

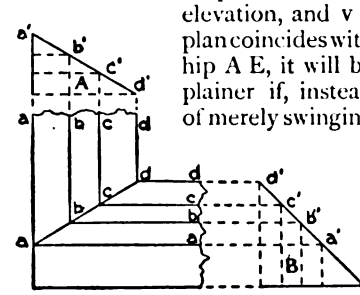

FIG. 15.

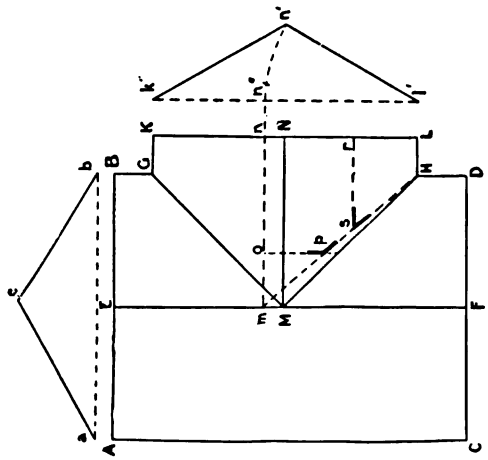

FIG. 16.

down the small piece of line, V x, we use the larger piece V e'. While e' has been swung down to E^1, the plan of this point has moved from E to E_1, so that the true shape of the top bevel is v v E_1. This will be found to be the same as the top bevel for cutting the boarding; while the side bevel is that for applying to the edge of the boards.

After what has been already done, the treatment of valley rafters, as exemplified in Fig. 16, should be a simple matter. Having determined the complete plan of the roof, all that is required is to develop the side by rebatting it upon the eaves line as hinge.

In Fig. 16 the side H M N L has been rebatted upon H L, so as to give H m n L as the true shape of that side; by drawing O P at right angles to H L the top bevel

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for the lower end of the jack rafter has been obtained at P. The top bevel for the boards has been determined by drawing *s r* parallel to H L; the bevel is that shown at *s*.

The length and bevels for a valley rafter being obtained in a similar manner to that already described for hip rafters, except that no backing is required for valley rafters, it is unnecessary to repeat the process here. A little careful thought, after a close study of the principles enunciated in these papers, should enable any reader to obtain the bevels for almost any example of roof construction to be met with in practice.

THE COMPOSITION OF A WHITE ENAMEL.

By BERESFORD INGRAM, B.A., F.C.S.

THOSE readers of TECHNICS who are interested in the problem of porcelain enamelling, may be curious to learn what are the constituents—ordinary and (apparently) necessary—of a white enamel surface.

The ingredients are divided up into two parts. The first comprises the "ground mass," and consists of *silica* (in the form of white sand); *crystallised borax* (for fluxing); *fluorspar;* and *magnesium carbonate* (which reduces fusibility).

These are mixed in varying proportions, powdered, and fused, then again reduced to a powder, and to them are added *aluminium silicate* (in form of pipe-clay) and pure powdered quartz.

The second portion, or enamel proper, consists of *flint meal* (quartz and silicates of iron and aluminium); *tin oxide; saltpetre; ammonium carbonate; lead sulphate; magnesium sulphate; potassium carbonate; borax;* and sometimes *gypsum* and *arsenic.*

This list does not include those chemicals which are necessary to produce a coloured enamel, but only those essential to a white or cream covering.

Of course, the proportions vary a great deal, but an average enamel will contain:—

Flint meal	31%
Borax	18%
Tin oxide	18%
Lead sulphate	10%
Sodium carbonate	8%
Saltpetre	7%
Ammonium carbonate	5%
Magnesium sulphate	3%

The following facts will be invaluable when making experiments with the above enamels.

An increase in the percentage of lead lowers the melting-point, but also increases the mobility of the melted enamel; on cooling this may, or may not, separate out into patches.

An increase in the quantity of tin oxide is liable to cause the enamel to "spring off" when it cools.

If the percentage of lead salt be lowered, or if this constituent be left out entirely, the heat required to melt the enamel on is so much greater, that the article to be enamelled requires very careful handling in order to preserve its shape.

Decrease in percentage or absence of the tin oxide produces an enamel with no "body," *i.e.*, of glassy, semi-transparent nature. This has been found to meet all the requirements for articles which are not for ornamentation as well as use.

A decreased quantity of silica and an increased proportion of borax produces, with the lead, an enamel which is very easily fusible, but which lacks "body." Tin oxide remedies this; but the quantity of the latter which has to be added increases the cost of production so disproportionately, that it is found more economical to produce the enamel at the higher temperature. Again, the tin oxide, as mentioned above, is liable to cause the enamel to "spring off" on cooling.

One may have a great many enamels of varying percentage composition, each one suitable for its particular purpose, producing the exact colour, lustre, surface, and "body" that is required—in other words, the chemistry of the process may be, and often is, as nearly perfect as can be expected—but there will always be the difficulty of preventing the "crase" which is certain to follow; just as if the chemistry and physics of the process had definitely made up their minds not to agree.

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THE RADIATION AND EMANATION OF RADIUM.

PART II.

By E. RUTHERFORD, M.A., D.Sc., F.R.S.,
Macdonald Professor of Physics, McGill University, Montreal.

THE effect of the continuous production of the emanation on the radio-activity of radium will now be considered. Solid radium bromide, in a dry atmosphere, gives off very little emanation into the air. This is not due to stoppage of the production of the emanation, but to its inability to escape from the mass of radium. The emanation is stored up or occluded in the solid, and can only be released by heating or dissolving the radium.

Suppose that a small quantity of solid radium bromide, some time after it has been made, is heated in order to drive off the emanation, which is then drawn off and mixed with air in a closed vessel. The activity of the radium is at once diminished, and in the course of four or five hours reaches a minimum value — the activity, measured by the α rays, possessing only one-quarter of its original value. This gradual decay of the activity to a minimum is due to the dying away of the excited activity produced in the mass of the radium by the emanation stored in it. At the same time, the radium has almost completely lost, for the time, its power of emitting β and γ rays. This loss of activity by the radium is not permanent, for the radiating power of the radium spontaneously increases again, and, after a month's interval, has nearly reached its original value.

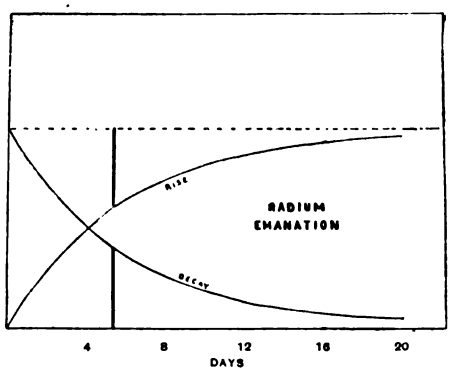

FIG. 6.—CURVES SHOWING DECAY OF ACTIVITY OF THE EMANATION, AND RECOVERY OF ACTIVITY OF RADIUM.

Let us now consider the emanation which was separated by heating the radium. In a closed vessel, its power of discharging an electrified body at first increases for several hours. This is due to the excited activity produced by the emanation on the walls of the containing vessel. The emanation loses its activity in a geometrical progression with the time. The activity falls to half value in four days, a quarter value in eight days, and so on. The curve of decay of activity of the emanation is shown graphically in Fig. 6. While the emanation is losing its activity, the radium from which it was separated is recovering its lost activity. This is due to the continuous production, by the radium, of emanation which is retained as already described: since the emanation itself radiates, the activity of the radium increases with the time. The curve of recovery of activity, due to the growth of fresh emanation, is shown in the same figure. The two curves of decay and recovery are complementary to each other. When the emanation has lost half its activity, the radium has spontaneously regained half of its lost activity. The sum total of the activity of the separated emanation, together with that of the radium from which it has been removed, is always equal to that of the original radium. It would appear as if the separated emanation and the radium were connected by some subtle and intricate mechanism, so that any decrease of the radiating power of the one is compensated by an equal increase in the other. The connection, however, becomes clear if it is remembered that radium is always manufacturing fresh emanation at a constant rate, and that the emanation is always losing its activity in consequence of changes occurring in it. When the emanation is driven off from the radium, fresh emanation is produced and stored up in the radium. If the emanation did not lose its power of radiating with the time, it would be expected that the activity of radium would continue to increase steadily with the time. Since, however, the emanation is always changing and losing its activity, a stage must be reached where the production of fresh emanation just compensates the loss of activity of the emanation stored up in the

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radium. Just as the population of a country remains constant when the number of births is equal to the number of deaths, so the activity of radium reaches a steady limiting value when the number of particles of emanation produced per second is exactly equal to the number of particles which lose their power of radiating in the same time.

In this continuous production of new kinds of active matter, which only radiate for a limited time, lies the key to the explanation which has been advanced to account for the phenomena of radio-activity. What process, occurring in radium, can account for its remarkable behaviour, for the spontaneous and unceasing projection of α and β particles, the rapid emission of heat, and the production of a gas endowed with new and surprising properties? It is obvious that some sort of chemical explanation is necessary to account for the appearance of new kinds of matter. But, on the other hand, the laws which control the production of this matter are very different from those of ordinary chemical change. Temperature, which has such a marked influence on ordinary chemical reactions, has no appreciable effect in changing the processes occurring in radium. The activity or heating effect is not affected by plunging radium into liquid air; and, so far as observation has gone, the rate of decay of activity of the emanation is unaltered by the most drastic physical and chemical treatment. If, however, it is supposed that the changes occur in the atoms of the radio-element itself, it is not to be expected that temperature would have much influence, for the experience of chemists in failing to break up the atoms into simpler forms, shows that wide changes of temperature have little effect in altering the stability of the chemical atom.

The theory that the phenomena of radio-activity are due to the disintegration of the radio-atoms was advanced more than a year ago by Mr. Soddy and the writer. This theory accounts in a simple way for all the complicated phenomena manifested by radio-active bodies, and welds together a series of apparently disconnected facts. Let us, for brevity, consider the application of this theory to explain the properties of radium alone. It is supposed that a very small number of the radium atoms—about one in every hundred thousand million will suffice—become unstable every second and break up with explosive violence. A part of the atom—the α particle—is expelled with great velocity. The expulsion of a particle which has a mass about twice that of the hydrogen atom, leaves the radium atom lighter than before, and must change its chemical and physical properties. The radium atom minus the expelled α particle, on this view, constitutes the atom of the "radium emanation." The atom of the emanation is also unstable; and, on an average, half of the total number produced break up in four days, each atom as it breaks up expelling another α particle. The emanation as a result is changed into another type of matter—emanation X, as it has been named—which behaves as a solid. This, in turn, is unstable, and the process of disintegration goes on from stage to stage till in the fifth change, in addition to the α particle, the β particle is thrown off with its accompaniment, the γ ray.

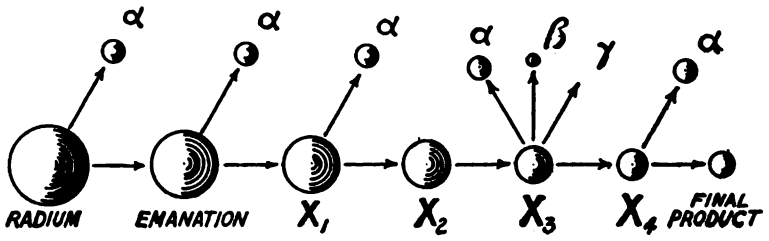

FIG. 7.—DIAGRAM TO REPRESENT THE DISINTEGRATION OF A RADIUM ATOM.

The different substances produced as a result of the disintegration of the radium atom, together with the nature of the rays emitted at each change, are shown diagrammatically in Fig. 7.

At least five distinct substances are produced as a result of the disintegration of the radium atom. The emanation is a chemically inert gas, while the succeeding products behave like metallic substances which are readily soluble in some acids, and are volatilised by heat. Each of these substances differs from an ordinary chemical element, inasmuch as it is not permanent, but is continuously and rapidly changing into another kind of matter. The products of the disintegration of the radium atom may thus be considered as transition elements which have a very limited life. Each of the products is transformed according to a definite law, and at a perfectly definite rate. After any interval t, the number of atoms, N, of any given kind of matter which

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remains unchanged, is given accurately by the equation, $N = N_0\epsilon^{-\lambda t}$, when N_0 is the initial number of atoms present, λ is the constant of change, and ϵ is the base of the Napierian logarithms. The time, T, which elapses before half the amount of each transition element is transformed is shown in the following table :—

Name of Substance.	Time, T.	Remarks.
Radium		
↓		
Emanation	4 days	1st product.
↓		
Emanation X (1st change)	3 minutes	2nd product.
↓		
Emanation X (2nd ,,)	21 minutes	3rd product.
↓		
Emanation X (3rd ,,)	28 minutes	4th product.
↓		
Emanation X (4th ,,)	very slow	5th product.
↓		
Final product		

The transformations of each of the products of radium, with the exception of the third, are accompanied by the emission with great velocity of α particles alone (Fig. 7). It is remarkable that the β and γ rays are only emitted during the changes in the fourth product, *i.e.*, during the last *rapid* change which takes place in the radium atom.

The fifth product of radium differs from the others in its extremely slow rate of change. The evidence, so far obtained, points to the conclusion that probably several hundred years would be required before half this matter is transformed. Since this substance is being continuously produced by the radium, and changes very slowly, it should gradually collect in some quantity in matter which contains radium. There is at present a good deal of evidence that the radio-active substance, separated from pitchblende by Marckwald, and called by him *radio-tellurium*, is in reality the fifth product of the disintegration of the radium atom.

Since the radium products are unstable and rapidly breaking up, we cannot regard them as identical with any known kind of stable matter.

Each of the radio-active products is found to possess distinctive chemical and physical properties which serve to distinguish it, not only from the preceding and succeeding products, but also from the parent element. The emanation is a heavy gas, which can be condensed by the action of extreme cold: like the gases of the helium-argon family, it is chemically inert. On the other hand, the solid products derived from the emanation are soluble in some acids; they are volatile at high temperatures, and can be partially separated from each other by their difference in volatility or by electrolysis.

With the exception of the emanation, none of the products of radium has been collected in sufficient quantity to be examined by direct chemical methods. The amount of each product to be obtained from a given quantity of radium depends on the rate at which it breaks up. When a state of radio-active equilibrium is reached, the number of atoms of any product appearing in unit time must equal the number disappearing; but, since the products break up at different rates, the number of atoms must be greater in the case of the more slowly changing product. It can be calculated that the weight of emanation (half of which breaks up in four days) obtainable from 1 gram of radium bromide is about 1/100 of a milligram; while the weight of the fourth product (half of which breaks up in twenty-eight minutes) is about 3/100,000 of a milligram—a quantity too small to be detected by the chemical balance. Thus it appears that the radio-active products resulting from the disintegration of the radium atom can never be collected in any great quantity on account of their limited life. The inactive products, however, must increase in quantity so long as there is any radium present, and we may hope to find them in radium ores in measurable quantities. The inactive products of radium are the expelled α particles and the final product.

Now the mineral pitchblende, in which radium occurs, contains in small quantity a large proportion of the known elements; the presence of the rare gas helium is noteworthy. Helium is only found associated with the radio-active minerals, and its presence in them has always been a matter of surprise. Mr. Soddy and the writer suggested, in 1902, that helium might prove to be a disintegration product of the radio-elements. This hypothesis received strong support from measurements of the mass of the projected α particles of radium, for, within the limit of experimental error, these appear to have about the same mass as the helium atom.

This suggestion has been verified in a brilliant manner by the recent experiments of Sir William Ramsay and Mr. Soddy. They found that helium always appeared in a closed tube in which the radium emanation

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had been stored for some time. The results indicate that helium is produced from the emanation as it gradually breaks up and disappears. There has been a tendency to assume that helium is a final product of the disintegration of the atom of the emanation, but the evidence so far obtained rather points to the conclusion that helium is in reality the expelled α particle. If this is the case, helium should be produced from each of the radium products which emit α rays; but the experimental difficulties in an investigation of this character are so great that progress must necessarily be slow.

The production of helium by the radium emanation is of extreme importance, as it is the first well-authenticated case of the transmutation of one element into another. This process of transmutation is of a very special character, for it takes place spontaneously, and at a rate that is independent of our control. In order to explain the production of helium from radium on strictly chemical lines, it has been suggested that helium is not a true element, but is in reality an unstable compound of helium with some known or unknown element, and that this compound is steadily breaking up with the liberation of helium. It must be borne in mind, however, that this postulated compound is very unique in character, for it is necessary to suppose that, unlike any other molecular compound, it breaks up with the expulsion of charged particles moving with enormous velocity, and that the energy liberated during these changes is about one million times greater than the energy liberated in the most violent chemical reaction. In addition, it is necessary to suppose that the process by which helium is liberated is unaffected by wide changes of temperature—a result never before observed in any chemical reaction.

So far as observations have yet gone, radium is a true element in the ordinary accepted chemical sense. It has a definite spectrum and atomic weight, and in chemical behaviour is closely allied to the well-known element barium. On the disintegration theory, the helium and the radio-active products appear as a consequence of the disintegration of the radium atoms. The difference in the two points of view is, to a large extent, one of nomenclature alone. The chemical atom is defined as the smallest chemical unit which enters into combination with other substances, and which cannot be broken up by the action of physical and chemical forces at our disposal. This is true, so far as we know, in the case of radium; for the breaking up that does occur is spontaneous, and cannot be accelerated or retarded by chemical or physical agencies.

Taking into account the novel character of the changes occurring in radium, and the enormous emission of energy, it appears more reasonable to suppose that these appear as the result of changes of quite a new character in matter—a breaking up of the chemical atom rather than of the chemical molecule.

Since radium is continuously breaking up with the expulsion of α particles and the production of new kinds of matter, a given quantity of radium must, in the course of time, disappear as such, and be transformed into inactive substances. It can be calculated that, in a gram of radium bromide, about half a milligram is transformed per year. In the course of about 1500 years half the radium present has been changed. If the whole world had been initially composed of pure radium, the amount of radium remaining 30,000 years later would not be more than one part in a million, *i.e.*, about the amount observed to-day in a good specimen of pitchblende. Since there is every reason to believe that the earth's crust is very much older than this, we are forced to the conclusion that radium must, in some way, be continuously produced from the materials of the earth. In looking for a possible parent of radium, the elements uranium and thorium both suggest themselves, for both fulfil the necessary condition of having an atomic weight greater than that of radium, and both are always found in minerals from which radium is derived. In addition, both of these elements have a very long life compared with radium. Since the activity of uranium and thorium is less than one-millionth of that of radium, its life should be about one million times longer, *i.e.*, a length of time of over 1,500 million years would be required before half the uranium present has been transformed. In some respects uranium seems the most likely parent of radium, for minerals rich in uranium are found to contain the most radium, while minerals rich in thorium often contain little radium. It remains for future work to give a definite answer to this question. If radium is produced from uranium, radium would occupy the same position in regard to it as the radium emanation does to radium, the only difference being that radium has a much longer life than its emanation. After the lapse of a few thousand years, the quantity of radium present in the mineral would reach

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a constant value, the production of radium balancing the loss by disintegration. The quantity of radium present in a mineral should, on this view, be always proportional to the amount of the parent element.

Much attention has recently been directed to the distribution of radio-active matter in the earth's crust and atmosphere. Its presence and amount have been determined by observations on the rate of discharge of an electroscope—a method transcending in delicacy even spectrum analysis.

The experiments of Elster and Geitel, J. J. Thomson, Strutt, and others, have shown that radio-active matter, while found in the greatest quantity in the mineral pitchblende, is widely diffused in nature. Radio-active emanations occur everywhere in the atmosphere, in well water, in hot springs, and in surface water. Elster and Geitel have found that the earth's crust is all more or less radio-active. If air is sucked up through a pipe let down into the ordinary garden soil, it is found to be impregnated with emanations. The amount of radio-active matter varies in different localities, but is most marked in clays and in the mud obtained from hot springs.

Since the presence of radio-activity is an indication that matter is breaking up with an enormous emission of energy, it is natural to ask what part radio-active substances play in cosmical physics.

On the assumption that the earth was formerly a molten mass, Lord Kelvin has estimated that to cool down to its present state it would require a period of from twenty million to one hundred million years. This calculation places a definite maximum limit to the time that has elapsed since the earth became cool enough to support life. In Thomson and Tait's "Natural Philosophy," Appendix E, the following sentence occurs, after a discussion of the probable age of the sun and earth: "As for the future, we may say, with equal certainty, that the inhabitants of the earth cannot continue to enjoy the light and heat essential to their life for many million years longer, unless sources of heat—now unknown to us—are prepared in the great storehouse of creation."

In the light of the discovery of radium and other radio-active substances, which in their changes are able to emit an enormous amount of energy, this remark seems almost prophetic. Assuming the average temperature gradient (1·50° Fahrenheit per foot descent from the earth's surface) and the conductivity of the rocks of the earth taken by Lord Kelvin, it can be calculated that the amount of heat conducted to the earth's surface each year and lost by radiation could be supplied by the presence of radium (or an equivalent amount of other radio-active matter) to the minute extent of about five parts in ten thousand million by weight. The observations of Elster and Geitel show that the amount of radio-active matter present in the soil is of this order of magnitude. Thus it does not appear improbable that the temperature gradient observed in the earth may be due to the heat liberated by the radio-active matter distributed throughout it. If this be the case, the present temperature gradient may have been sensibly constant for a long interval of time, and Lord Kelvin's computation may only supply the minimum limit to the age of this planet. Thus the earth may have been at a temperature capable of supporting animal and vegetable life for a much longer time than estimated by Lord Kelvin from thermal data. Similar considerations apply to the question of the sun's heat; for the presence of radium in the sun, to the extent of about four parts in one million by weight, would of itself account for the present rate of emission of heat. The discovery of the radio-active elements, which in their disintegration liberate enormous amounts of energy, thus increases the possible limit of the duration of life on this planet, and allows the time claimed by the geologist and biologist for the process of evolution.

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ELECTRIC WAVES.

Part I.—Preliminary Explanations.

By J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London.

THE subject of Electric Waves has been so much popularised and brought within the region of every-day knowledge by reason of its practical application in wireless telegraphy, that it has ceased to appeal merely to the pure physicist, and has become a matter of general interest.

Without doubt one of the greatest achievements of the human mind has been the accumulation of that body of evidence, partly experimental, partly theoretical, which enforces the belief in a space-filling æther or medium, not of the nature of ordinary matter, and yet possessed of such a collection of properties that it is just as real as any of the things we can see or feel. We are so much accustomed to make "seeing and feeling" our test of reality, that many find it difficult to form a conception of a medium having properties which seem chiefly negative when compared with those of ordinary gravitating matter. This æther must be universal in the sense of not being confined to limited portions of space. It is not capable, so far as we know, of being removed entirely from any space, or compressed or accumulated in excess in any space. We have no evidence that it is gravitative, or subject to attraction by ordinary chemical matter. It does not seem to resist the motion of such matter through it. It is, therefore, intangible and cannot be stored, condensed, or otherwise rendered evident to the sense of touch; and it is, therefore, quite different in nature from a rarefied gas. We have no proof that it is atomic in structure, and the descriptive terms we employ to define it are, therefore, the negation of all, or nearly all, the qualities characteristic of ordinary matter.

Nevertheless, if views beginning to be held are valid, æther is much more fundamental and basal in character than gravitating matter. In fact, we may perhaps even say that without æther there could be no matter; any more than there can be a sound wave in a place where there is no air, or a whirlpool where there is no water.

Space, therefore, is not a mere mathematical abstraction. In one sense, we may say that æther is space, and that material substances exist in space, or can be moved in space, only because the æther exists and they can be displaced in it. Hence physicists have enforced the view that the primary property of matter, *viz.*, inertia, is the primary property of the æther, and that all inertia is simply the inertia of the æther. According to this opinion, when we attempt to set a heavy fly-wheel or vehicle in motion, the obstacle to the acquirement of velocity apart from friction is the inertia of the æther, and we are overcoming this inertia in producing acceleration of any kind. Hence one primary property of the æther must be that changes are not spontaneously produced in it, but that every change involves the operation of something called a "force." It is possible that all our notions of causation require revision and a change of phraseology; but the discussion of this point would lead us away from physics into metaphysics. In a future age the notion of "forces" may be abolished altogether; but at the present time the word and idea are perhaps necessary, if only to avoid circumlocution.

We find ourselves, therefore, in this position. The effort to look below the surface of physical phenomena invariably brings us to the notion of a universally diffused, supermaterial or fundamental medium, which is a requisite of thought, were it merely to enable us to avoid the notion of action at a distance which has always been so repugnant to physical philosophers. We have then to assume certain primary qualities in this medium, and the one which it is first necessary to postulate is that of inertia.

In the next place, we have to postulate for this universal medium some kind of elasticity. The æthereal hypothesis first originated from vague ideas that some supersensual medium was involved in the production of the phenomena of Light, Heat, and Electricity; but the attempt to expound optical effects by its aid rendered it necessary to endow the medium with an elastic resistance to change of some kind. Without this assumption it would be impossible to explain the transmission through it of a wave or impulse of any kind. The nature of this elasticity next came

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in question. In scientific language, we call a body elastic when an attempt to produce some change in configuration in it calls forth a resistance which increases with the change. Hence there are many varieties of elasticity. We have, for instance, in the case of solid material substances two kinds of elasticity. There is first, *Volume-Elasticity*, or the resistance offered to change in bulk; and secondly, *Form-Elasticity*, or the resistance offered to change of shape. A solid body resists being squeezed or expanded. It also resists being bent, stretched, or twisted. Within certain limits this resistance is proportional to the change in bulk or form, or to the deformation. Hence to create such a change necessitates the expenditure of work done against the elastic resistance. This work, however, is stored up as potential energy, and can be recovered again by allowing the elastic body to resume its original condition. In the case of liquids and gases there is resistance to change of bulk, but no resistance to change of form; in other words, these bodies have volume-elasticity but not form-elasticity. A body is therefore said to have elasticity when work or energy has to be expended on it to make some kind of configurational change, that work being stored up as potential energy and recoverable again on the release of the constraint. It is unquestionable that energy can be stored up in the æther in large quantities. The question arises: In what form is this energy stored, and what is the nature of the corresponding elastic reaction?

The process of interpreting to ourselves the operations of Nature always involves an effort to visualise the hidden machinery. We seem to receive most satisfaction from so-called *mechanical* explanations. When we can picture to ourselves the nature of the operations as a change in form or a movement of something, we think we understand them better. Probably this is owing to the fact that the only things we can depict clearly in thought are motions of some kind.

Our notions of elasticity are all gathered from our experience of the elasticity of matter. Having become possessed of the atomic idea, and picturing to ourselves the atoms of material bodies as little agglomerations separated by empty space, we easily pass on to the idea that expansion or contraction in matter in the mass consists in the recession or approach of these little masses or molecules; we furthermore call in the notion of repulsion or attraction between the molecules, and thus create the simple idea of volume elasticity out of the complex one that the molecules of bodies resist being drawn away from or approximated to each other.

In the same manner we picture to ourselves the molecules or parts as resisting displacement relative to one another, and hence we account for form-elasticity, resistance to bending, shearing, stretching, and so on.

If, however, we try to apply this process of thought to the æther, we see that we have no right to do so in the absence of evidence that the æther is atomic in structure. If the æther is assumed to be a homogeneous non-atomic medium, then no such property as volume elasticity can be postulated for it. If it does not consist of discrete portions it cannot be assumed to be compressible or expansible. This at once rules out any consequences such as the possibility of waves in it like air waves, which essentially depend upon volume elasticity for their production.

Space will not permit even the briefest sketch of all the various æther theories which have been propounded. The æther was at one time assumed to be a jelly-like solid, possessing an elastic resistance to shearing; this hypothesis ruled the field in the early part of the 19th century. Then it was seen that this theory did not fit in with many important facts, and in 1839 MacCullagh suggested the idea of a fluid æther possessed of rotational elasticity. In this hypothesis it was assumed that each small part or element could be moved about freely, but offered elastic resistance to rotation. The æther was, in fact, imagined to be a perfect fluid, each element of which elastically resisted being twisted, but not being moved irrotationally.

Lord Kelvin suggested a possible mechanism for MacCullagh's æther by supposing that each particle of the æther resembled a gyroscope and opposed gyrostatically any torque applied to it. More recently Professor Larmor has developed this conception. Clerk Maxwell, however, made a wholly fresh departure in bringing the idea of an electromagnetic medium within the grasp of mathematical analysis.

Newton declared his belief in a "most subtle spirit which pervades and lies hid in all gross bodies; by the force and action of which spirit the particles of bodies mutually attract one another at near distances, and cohere if contiguous, *and electric bodies operate to greater distances*."

In this last paragraph of the *Principia*, Newton's prophetic mind had already antici-

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pated the suggestion of Ampère and Faraday that the luminous and electro-magnetic media were one and the same.

It remained, however, for Maxwell to give the first proof that this was more than a mere speculation, by showing theoretically that the velocity with which an electro-magnetic impulse must travel through the electro-magnetic medium is identical with the velocity of light. The phenomena of optics show that the æther transmits a wave motion. Hence it follows that it must be capable of containing energy in two forms, *viz.*, a kinetic form and a potential form; for otherwise wave motion is impossible. If this wave motion is considered to involve an actual motion of ordinary matter of some kind, then the kinetic energy per unit of volume will be represented by $M^2/2d$, where d is the density of the matter and M is the root-mean-square value of the momentum contained in the unit of volume. Also the potential energy per unit of volume will be represented by $D^2/2p$; where p is the coefficient of pliability, and D is the root-mean-square value of the displacement of each element in the unit of volume. The velocity U, with which a wave or disturbance will travel through the medium, is dependent on the ratio of elasticity to density, in accordance with the equation $U^2 = 1/dp$.

The quality called the *pliability* is the reciprocal of the quality usually called the elasticity of the medium.

When a permanent wave motion is established in the medium, the kinetic and potential energies contained in each unit of volume are equal.

Further consideration shows that the medium must also be such as will account for the facts of electricity and magnetism—must possess the power of storing energy in two forms, *viz.*, magnetic and electric. If we start a current A in a wire, the energy stored up magnetically in connection with it is $\frac{LA^2}{2}$ where L is a quantity called the *inductance* of the wire. If we charge a condenser electrostatically, the energy stored up in it is measured by $\frac{CV^2}{2}$ where C is the capactity of the condenser, and V is the potential difference of the plates.

The dielectric between the condenser plates has, however, a certain specific inductive capacity or dielectric constant. Let this be called k. The space round the current-carrying wire has a certain magnetic permeability. Let this be denoted by μ. Then it is not difficult to show, when we are using rational electric and magnetic units, that the electrostatic energy stored up per unit of volume of the dielectric is measured by $D^2/2k$, and the magnetic energy stored up per unit of volume round the current is $B^2/2\mu$.

In these expressions B is the magnetic flux density or magnetic induction in the space, and D is the electric displacement or electric strain in the same space.

When we are discussing the production of *motional waves* in a medium such as air or water, we have to consider four quantities. Two of them are dynamical, *viz.*, the *momentum* of the moving particles, and their *displacement* from their positions of rest: two of them are constants defining qualities of the medium, *viz.*, its *density*, and its *pliability* or elastic yielding to stress. In the case of electric phenomena we are also concerned with four quantities—two of them dynamical *viz.*, the magnetic flux density or *magnetic flux* in the magnetic field, and the *electric strain*, or polarisation or displacement in the electric field; and two of them constants of the medium, *viz.*, its *permeability* and its *dielectric constant.*

Just as the velocity of a motional wave, such as a sound wave, is determined by the relation that the square of the velocity is equal to the reciprocal of the products of the density and pliability of the medium, be it air or any other material fluid; so also it can be shown that the square of the velocity of propagation of an electromagnetic wave through the electromagnetic medium must be given by the reciprocal of the product of the permeability and dielectric constant of that medium.

From many points of view it is preferable to regard the space-filling æther simply as an electromagnetic medium having definite electric and magnetic properties defined by its permeability and dielectric constant, and to work with these fundamental notions rather than with suppositions or hypotheses as to the structure of the æther. We really know nothing about the inner structure of the æther, whereas we do know that the permeability and dielectric constant of æther are specific qualities of it not very different from that of the best vacuum we can produce. Since, however, in measuring the magnetic permeability and dielectric constant of any other material, all we can do is to compare these with the corresponding properties of the æther, this last medium becomes our standard of comparison. We can, if we please, assign the

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value unity or any other numerical value to either of these constants of the æther. Nevertheless, when we have selected one of these the other becomes fixed, because there is always between them the definite numerical relation that $U^2 = 1/k\mu$, where U is the velocity of radiation. The most extensive experiments have shown that the velocity of light and that of the longer Hertzian waves are both equal to thirty thousand million centimeters per second, or 3×10^{10} cms./sec. Accordingly the relation between the numerical values of the two æther constants k and μ is expressed by the equation

$$k\mu = \frac{1}{9} 10^{-20}$$

As all electrical students are aware, there are two systems of electrical units, the electrostatic and the electromagnetic. In the first of these we take k to be unity, and in the second we assume μ to be unity. We know, as above, the numerical value of the product of the æther permeability and æther dielectric constant, but we do not know the value of either separately. It is, therefore, as if we knew the value of a couple or torque, but did not know the value of the force and arm independently.

We have further to consider the manner in which the two states, called the electric strain and the magnetic flux in the æther, are related. Both of these effects take place along certain lines in space, and hence we speak of *lines of electric strain* and *lines of magnetic flux*. Moreover, we may mark out all space into tubular spaces which are bounded by lines of the above kind, and these are called *tubes of strain* or *tubes of flux*.

Now the fundamental property of a tube of electric strain is that when moving sideways parallel to itself, it gives rise to a tube of magnetic flux at right angles to itself and its direction of motion. Again, the sideways motion of a tube of magnetic flux gives rise to a tube of electric strain. When these relations are mathematically considered they show that the tubes of strain and flux must be related to each other in the same manner as a *squirt* and a *spin* or *vortex* in a liquid, or as a *force* and a *torque* in mechanics. This is a very difficult notion to grasp, and yet it lies at the root of the subject. It is easy to put it into a purely mathematical form, but not so easy to present a proof of it divested of mathematical symbols. We may, however, attempt to assist the reader, as follows:—

Imagine a very large cistern of water, and that below the surface we place a fire-engine hose-jet connected to a supply of high-pressure water by a flexible pipe, and thus make a squirt of water in water. Inside the space occupied by the squirt of water, the water is moving forward. Outside this space, on all sides, the water must be moving backward or against the jet. If this were not the case there would be an accumulation of water in the direction of the squirt. The result is that the squirt is surrounded by a vortex motion. Everyone who has examined the motion of the smoke in a smoke ring blown from the mouth with tobacco smoke, or from the funnel of a locomotive, knows that it resembles the motion of an indiarubber umbrella ring when placed on a round stick which it fits somewhat tightly, and pushed along. The ring turns over and over, rotating round the circular axis of the ring. The squirt of water in water would therefore surround itself with vortex rings of water. If the squirt is moved parallel to itself and at right angles to its own direction, the vortex motion will continually be created on one side and ceasing on the other; hence the result of the lateral movement of the squirt is the production of a vortex, the direction of which is at right angles to the motion of the water in the squirt, and also to the motion of the squirt as a whole.

(*To be continued.*)

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FUELS FOR INTERNAL COMBUSTION ENGINES.

By C. H. NEW, F.I.C.

THE popularity of the motor-car has entailed marked development in the internal-combustion engine, and consequently created a demand for a suitable fuel. In the earlier days of the motor-car this was forthcoming; but now the question of supply as well as that of quality has to be reckoned with. The former is a subject more within the sphere of the technologist than of the motorist; but as regards quality (that is to say, the essential characteristics which determine the fuel value of a motor-spirit), there is no reason why users should not be able to thoroughly grasp the technical points involved, and so place themselves in a position to appreciate a desirable spirit, independently of its trade name or brand.

The following is an endeavour to present impartially the characteristics of a good motor-spirit; the points of merit being those to which designers and makers of explosion engines attach most importance, in their desire to obtain the best results.

Quality.

In the first place, it is desirable to warn motorists against using or accepting the term *petrol* as a generic title for motor-spirit of petroleum origin. It is the trade name for an excellent product made to meet the demand for a fuel for motor launches so far back as 1892, and subsequently used for motor-cars; but confusion and disappointment are likely to arise from applying the name to all kinds of motor-spirit, for the name is associated with a certain standard of quality to which all spirits do not attain.

In general, a desirable motor-spirit should vaporise completely within a range of temperature as narrow as possible, a feature due to homogeneity and denoted by a constant boiling-point. It should also yield sufficient volatile products, at all ordinary climatic temperatures, to enable the engine to be started with ease and certainty, *i.e.* the vapour tension should be high. The absolute degree of homogeneity must be regulated by expediency; the spirit must moreover be free from corroding products which would injure the valves and cylinders. Lastly, the specific gravity should be constant within certain limits. This last characteristic requires special consideration and some explanation.

Hitherto, the motorist has depended solely on the reading of his densimeter as a guide to the quality of a motor-spirit. In the earlier days the specific gravity of the spirit was a useful guide; but an increasing demand has necessitated an extension of the sources of supply, and has led to the introduction of motor-spirit which can no longer be accurately judged by the old standard of density. In cycle and motor literature, this standard is often quoted in the absence of detailed knowledge of the modern methods of production. In the face of such knowledge, it becomes evident that a density of 0·68 at 60° F. is no longer absolutely essential for a good motor-spirit. In fact, it is now quite possible to attain to this old standard in the matter of density, at the expense of the other and more vital features which constitute a good motor-spirit.

To many this may seem such a revolutionary statement, and so contrary to all that has been looked upon heretofore as a criterion of quality, that it will be advisable to present a few results, showing the relation between density and quality. These results have been obtained from ordinary commercial products, and are not isolated examples. Moreover, it is as well to emphasise the fact that the points of merit in a fuel, on which the deductions are based, are those which commercial men, desirous of securing the best fuel for their respective makes of engines, stipulate for in their contracts. Let us summarise the position. The two chief features in a desirable spirit are (1) complete vaporisation in the lowest range of temperature possible; (2) Reasonable volatility, which may be indicated approximately by the percentage of spirit volatile at the temperature of boiling water, viz., 212° F. These features have to be compared with the old standard of 0·68 density, and the possibility of a good spirit at a different (and presumably higher)

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density. In the following table we have the comparative figures :—

Sample.	Range of Total Vaporisation Temperatures.	Density at 60° F.	Percentage of Volatile at 212° F.
No. 1	89° F.	0·676	81·60
,, 2	85° ,,	0·683	89·00
,, 3	77° ,,	0·710	95·30
,, 4	62° ,,	0·700	90·00
,, 5	75° ,,	0·700	95·00

It will be seen that it is quite possible to obtain a spirit of 0·7 density, which is even superior to one of 0·68 density; so that, within reasonable limits, too much importance must not be attached to density. On the other hand, it must not be inferred that a spirit which tests 0·7 is by analogy "all right." The volatility and range of vaporisation are the figures from which to draw conclusions. The object of the above table is chiefly to show that the density alone is untrustworthy as a guide to quality.

This change in the standards of quality is necessitated by the widening of the motor-spirit field. For instance, in early days the density of coal might have been a very fair guide to those who used it as a fuel to raise steam; but increased demand led to fresh coal-fields being exploited: the products of these fields, when washed and sorted, yielded good steam coal, though its density was not the same as that of the original supplies. The chemical investigation of the new supplies proved that the real test of merit was not solely the density, but freedom from ash and impurities. Knowing the essential factors to-day, a commercial man would not contract for coal on its density, but on the basis of the percentage of total carbon and ash.

The position of motor-spirit is precisely similar. Users have to awake to an understanding of what is taught by the range of total vaporisation and volatility. If they would make a point of insisting on at least the former standard, coupled with the price and density, they would be in a position to obtain what they want, *i.e.*, the best spirit for their purpose. It will be noted that the element of density has not been ignored. This may seem strange, seeing that the value of density as a criterion has been unhesitatingly discredited. The reason is simple. Though the important thing is to prove to the motorist that blind use of a density test alone is nowadays quite misleading, it may nevertheless be judiciously used as a check on range of vaporisation.

For instance, some little interest has been aroused in motor circles by the proposal to apply *nineties* benzol as a fuel. Now, apart from a number of considerations which are known (by those who are familiar with the benzol trade) to put the use of benzol out of court, the proposal affords an apt illustration of the need for using the density as a check. One of the chief advantages claimed for benzol is that there is practically no range of vaporisation, as benzol can be obtained virtually homogeneous. From one point of view it would therefore seem to be an almost ideal product. But this apparent virtue is heavily discounted when we find a density of 0·88 and a vapour tension so low that you cannot "start up" with benzol *per se*. This example tends to emphasise the claims for a change from the density test to the triple standard indicated at the outset, viz.: (1) Range of vaporisation; (2) Volatility; (3) Density.

While urging users to insist on obtaining these data from manufacturers and vendors, it is as well to make it clear that there is nothing unreasonable in demanding such information. It is quite conceivable that there may be interested opposition to the general adoption of such a practice, but on the other hand it is certain that the user would only be asking for information which, in the ordinary course of business, is now afforded to critical purchasers. It is not unreasonable, therefore, to expect the average motorist (who is not likely to be incompetent either on intellectual or educational grounds) to seek the same criteria. The interests of motorists already need some such form of protection: users of drugs and artificial fertilisers are already legally protected to the same extent, apart from the protection voluntarily afforded by large firms who wish to ensure their special products reaching users intact, and take steps to attain this end. I do not hesitate to say that there are motor-spirit manufacturers who would do the same if asked.

Supplies.

Not unnaturally, there is a fear among users of motor-spirit that a shortage of raw material may result in an advance in price. Last year something of this kind was experienced, and attention was at once drawn to the desirability of finding other fuels than petroleum-spirit. Very well-advised and able efforts are being made to obtain untaxed alcohol suitable for use as a

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motor fuel; but although much sympathy and support is, and rightly should be, extended to this movement, it does not relieve the pressing needs of the moment, since it will obviously be some time before the Inland Revenue machinery is adapted to the new conditions which will be entailed. There is every indication that untaxed alcohol will, in due course, be available for motorists. But while welcoming the possibilities thus opened up, it is as well to consider some other aspects of the case.

So far, experiments with alcohol have principally been made on engines built for petroleum products. The alcohol motor has yet to be designed and perfected. Untaxed alcohol will give engineers an impetus in this direction, in the same way that the Light Locomotives Act gave the present type of motor a chance. Germany may be cited as affording the chief indications as to the possibilities of alcohol, even when used in the present type of motor; but, without any desire to throttle enterprise or discourage alcohol enthusiasts (of whom the writer is one), it is absolutely necessary to remember that the measure of success which has attended the use of alcohol in Germany does not afford an accurate standard for predicting the prospects of its use in this country. The conditions in the two countries are not identical. There is a tax on motor-spirit in Germany, but none here. Granted that we have obtained untaxed alcohol, there is still a discrepancy. Would the Germans use alcohol at all if they could obtain motor-spirit under equally advantageous conditions? Is it not rather a case of contenting themselves with cheap alcohol in lieu of the more expensive taxed motor-spirit? We have no need for such a substitution in this country, but as we may develop the alcohol motor with the advent of untaxed alcohol, by all means let us have both.

What, then, are the prospects with regard to supplies of motor-spirit? Is there reasonable ground for anticipating a scarcity? Whatever interested opinions may be, the impartial investigation of statistics shows that no alarm need be felt in this connection. Competition may be reasonably trusted to keep prices within bounds. Any attempt to "corner" motor-spirit would undoubtedly very soon bring competitive producers into the field, and they would enter it with every prospect of success. The man who wants to see motor-spirit at the price of lamp-oil is not likely to do so. On the other hand, the recent scarcity has opened up supplies in plenty at a reasonable figure. As it is, prices are about 2d. a gallon lower than they were fourteen months ago. Now those who have not the opportunity to look personally into this question of supplies may well ask for some enlightenment as to what are the statistics referred to; where are these sources which promise an uninterrupted supply of spirit, and what is the quality of the resulting product as a motor fuel?

The statistics are the Government official returns of our import trade. To appreciate them it is necessary to consider the previous conditions of the trade. Until quite recently we were entirely dependent upon one source of supply; and motor-spirit, being a refined light petroleum distillate, its source was naturally the United States. The demand increased and the supplies became restricted. But last year the amount of light naphtha imported into Europe from the new sources of supply was greater than the total quantity previously imported in any one year from the United States; while the Eastern production has also very nearly doubled of late. Such is the general position, and the recently published Board of Trade Returns for 1903 give the figures for classified petroleum products, among which appears petroleum spirit —the raw material for the production of motor-spirit. Prior to last year or thereabouts all supplies came from the United States; but for 1903 we find the following enlightening figures:—

Roumania . . .	826,280	gallons.
Borneo	527,000	„
Dutch possessions .	5,295,440	„
	6,648,720	
United States . .	2,078,150	„

This disposes of the nature of the statistics, and also of the new sources of supply. Only the question of quality remains to be disposed of, and that can be most effectively and instructively achieved by reference to the preceding table (p. 181), in which the range of vaporisation, density, and volatility are compared. In that table samples Nos. 3, 4, and 5 are derived from the Eastern supplies and Nos. 1 and 2 from the United States.

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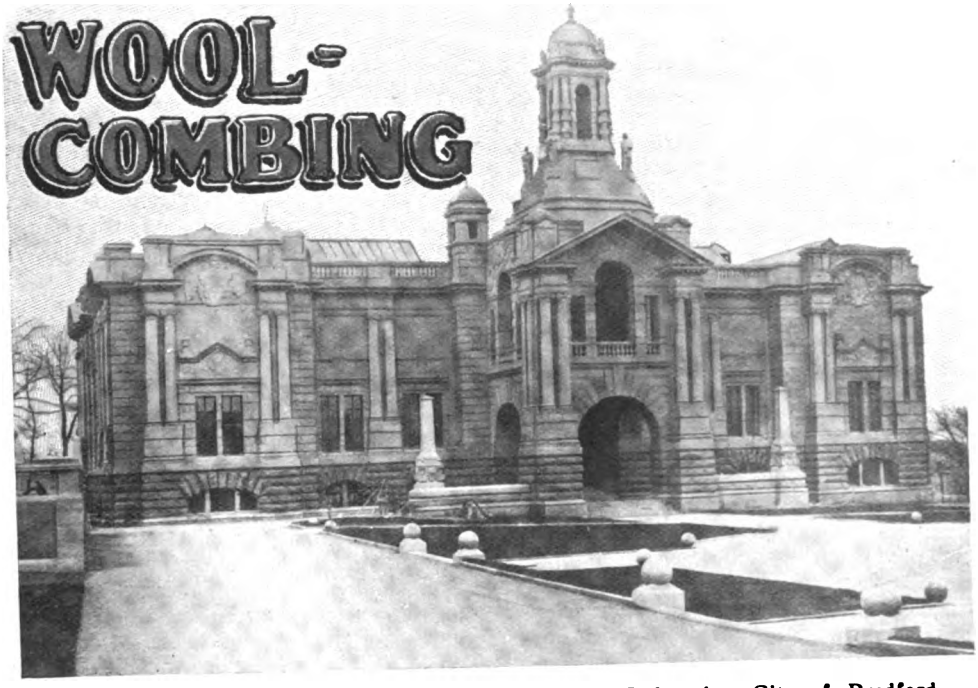
WOOL-COMBING



By ALDRED F. BARKER, Professor of Textile Industries, City of Bradford Technical College.

IN connection with the Cartwright Memorial Hall Exhibition at Bradford, opened by the Prince and Princess of Wales in May, it was natural to suppose that some space would be found in the Industrial Hall to demonstrate the conditions of industry obtaining during the Cartwright period. This matter was seriously considered by the Exhibition Committee, but unfortunately, lack of space excluded anything of the kind. There has been expressed in *Worstedopolis*, and elsewhere, such a desire for a complete and practical account of the development of machine wool combing, that it was felt some endeavour should be made to meet this want: hence the present series of articles under the headings of—

I. The Domestic Industries;
II. Hand Wool-Combing;
III. The Cartwright Era; and
IV. The Development of the Machine Wool Comb.

FIG. 2.—THE RIGHT HON. LORD MASHAM.
From the painting presented to the City of Bradford by W. C. Lupton, Esq., late Mayor.

There are three main objects which it is hoped these articles will fulfil:—

1. To illustrate the evolution of industry, and thus impress the inter-dependence between different sections of the industry.

2. To get back to the material itself, and counteract the tendency for the modern workman to base his ideas upon the machine instead of upon the material.

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FIG. 3.—TO ILLUSTRATE HAND CARDING.

3. To promote a full and true knowledge of the various machines employed in the wool combing industry.

4. To pay a tribute to Dr. Cartwright, to whom the Combing industry really owes so much; and further, to acknowledge, if only in some slight way, the great work which Lord Masham has accomplished in the interests of Bradford, culminating in his magnificent gift of the Cartwright Memorial Hall.

All the foregoing points will be noted in due course, but it may be well to give one or two simple demonstrations of them before proceeding further. Thus, in the *Life of Dr. Cartwright* (page 231), the following is found :—

"During a period of about nine years," Mr. Radcliffe said, "from 1793 to 1802, the machinery for spinning cotton yarn, with the ingenuity, practical knowledge, and persevering industry of the persons concerned in this branch, became so perfect as to enable the spinners to produce more yarn than could possibly be made into cloth by all the weavers Great Britain could collect for the purpose. The demand for cotton cloth was equal, during this period, to take off the whole produce of the spindle, if weavers could have been found to have made it into cloth; but this being impossible, the spinners began to export the surplus to the manufacturers abroad —into France, Germany, Russia, Switzerland, Holland, Spain, Portugal, Denmark, Sweden, etc., countries possessing a multitude of weavers formerly employed in weaving linen, silk, stuffs, etc., whose labour was to be had at half the price which was paid for such labour in this country."

In reading the foregoing, it should not be forgotten, that prior to 1793 the boot had been entirely on the other foot. The invention of the fly-shuttle by Kay had resulted in the weaver being continually obliged to "play" something like half his time for lack of yarn. The analogy with present-day conditions will no doubt strike many engaged in the textile industry.

Again, the overlooker of the present day, troubled with broken "slivers" on his Noble comb, or endeavouring by additional sets of rollers to draw off the "milkings," or considering the making-up of the fibres and reversing of the sliver on the Noble comb, as compared with, say, the Square-motion comb, undoubtedly gains insight and increased capacity from consideration of hand methods. The value of a detailed consideration in such matters as these might be further exampled, but there is no need to carry this further here.

Industrial Evolution.

Let us, in the first place, go back to the industrial conditions prevailing in the very early ages, and consider briefly but clearly the evolution which has taken place. In List No. 1 is given a brief summary of the evolution of industrial conditions, in which the sequence is most interesting, and might

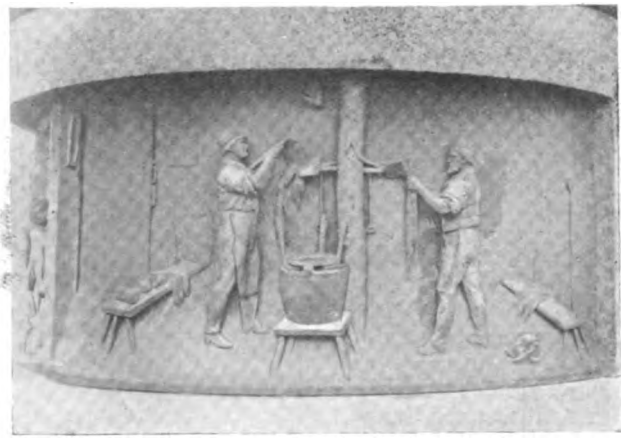

FIG. 4.—HAND COMBING.
From the monument to Lord Masham in Manningham Park, Bradford.

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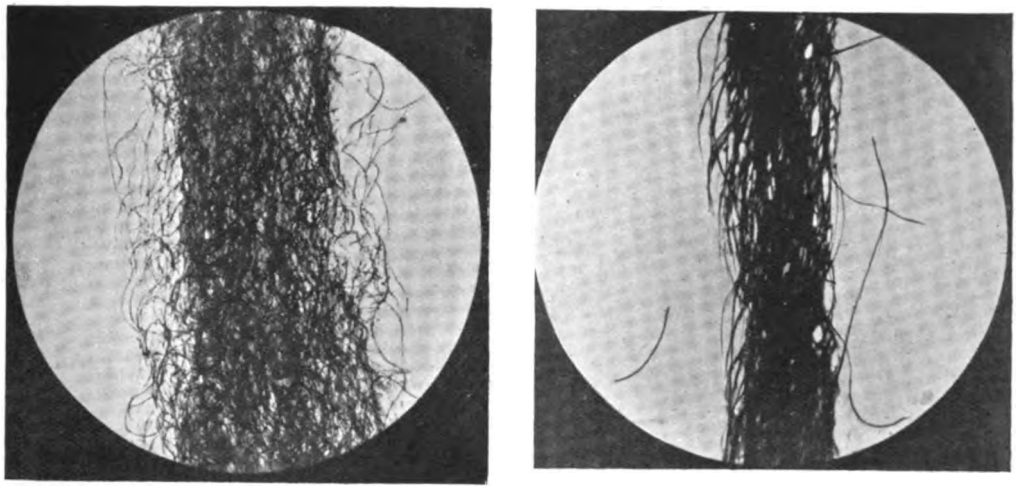

Carded Sliver. *Combed Sliver.*

FIG. 5.—SLIVERS.

be much enlarged upon. It will be sufficient to note, however, that the patriarchal age would naturally be followed by the village age; this latter would undoubtedly lend itself to a species of despotism; despotism would naturally result in a tribal system, and the moment the tribe had developed, slavery and serfdom come in, through prisoners captured in war and political and other offenders.

Then there comes the development of hereditary trades, and possibly at the same time the "Caste" system in the east, leading to the Feudal system of Western Europe, which in turn gave way to state-regulated industries, from which the pendulum swung to a free industry on the *laisser faire* principle, finally culminating in the tendency towards the self-regulating industry of the present day.

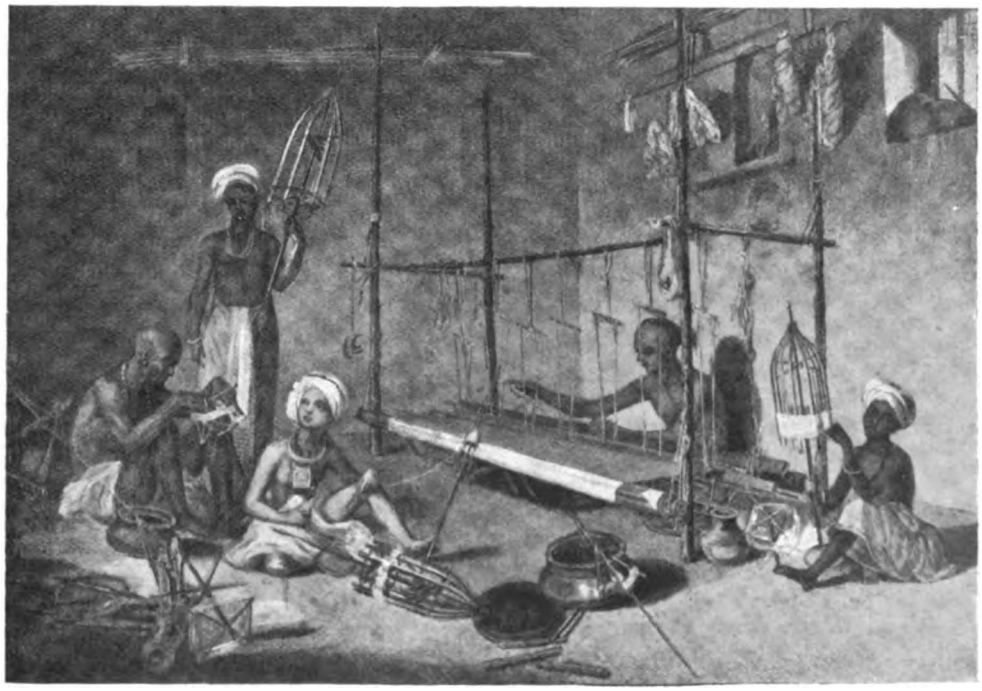

FIG. 6.—PRIMITIVE DOMESTIC ARTS.

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FIG. 7.—DISTAFF SPINNING, LATER FORM.

Those wishing to study this evolution more closely should read the *Factory System*, by W. C. Taylor.

Now let us turn our attention more closely to the industrial evolution in our own country, which we shall find will resolve itself under two heads :—

1. Conditions prevailing previous to the Factory System. (List No. 2, p. 188).

2. Conditions prevailing during the development of, or under the Factory System.

Upon turning to the consideration of the development of the Factory System (List No. 3), three concurrent influences are to be noted, *viz.*:—

1. Development of mechanical methods of manufacturing.

2. Development and organisation culminating in the Factory System.

3. Extension of markets.

Before detailed consideration of this list let us, in the first place, clearly consider the conditions of industries as they prevailed during the period which is defined as "entirely domestic," that is, up to 1690.

THE DOMESTIC INDUSTRIES.

Undoubtedly in the early ages of our race, spinning would be accomplished by the twisting together of filament by means of the fingers, unaided by any mechanical means. Of the difficulties of spinning there is marked indication in the fact that it is now considered as proved that weaving preceded spinning. This crude method of manipulation would soon be improved upon, however. Thus the following developments—all strictly domestic—may be noted :—

(*a*) Distaff spinning.

(*b*) Introduction of preparatory processes, *viz.*, carding and combing.

(*c*) Introduction of improved spinning implements, *viz.*, the Jersey or large wheel, and the Flax, or small wheel.

(*d*) Introduction and development of the hand loom.

In distaff spinning no preparation other than scouring would be given the material to be spun. Thus it would resolve itself into making up the necessary strand with the fingers, and then twisting it. This twisting operation would necessitate a free end to the sliver or thread. The idea of winding the spun yarn upon a spindle and allowing the end of the spindle itself to act as the free end carrying the yarn, and thus, along with the whorl, giving momentum, would no doubt naturally suggest itself. The following extract from the "Ancient Cities of the New World," indicates this method of working (page 110) :—

"These whorls are called 'malacates' by

FIG. 8.—THE JERSEY WHEEL.

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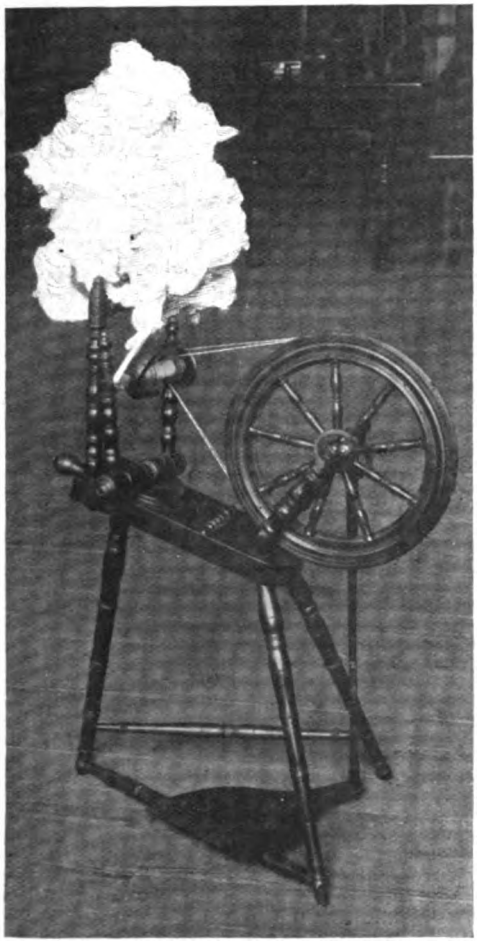

FIG. 9.—FLAX WHEEL.
This wheel, nearly 200 years old, is the property of Lady Ripley.

the natives, and are used by Indian women to this day. A round piece of wood or spindle-stick is introduced in the hole of the whorl, projecting about five inches from the lower plane, and about nine inches from the upper. The spinner, who is sitting, rests the point of her spindle on a varnished plate, and impels it round with her thumb and forefinger, twisting the cotton or wool attached thereto. In Mexico, rich ladies used a golden plate."

DESCRIPTION OF HAND CARDING.

Hand carding is a comparatively simple operation as compared with hand combing. The idea is simply to mix the fibres thoroughly —so that no knots or clusters of short fibres remain unopened—and then to draw out a sliver suitable for spinning. Two pieces of card-clothing nailed on to two flat boards of suitable size, with handles conveniently placed, are all that are here necessary; but considerable skill is necessary to take off the carded sliver in a roll suitable for being extended or "roved," and finally spun.

DESCRIPTION OF HAND COMBING.

The combing operation may be said to be a mixing, arranging and straightening, short fibre extracting, and sliver making process. It would be impossible to say which of these was the most important. Two hand combs are necessary for the operation. As hand-combing will claim our careful attention later, there is no need to consider it further here.

DESCRIPTION OF HAND SPINNING.

There can be no doubt that these two methods of preparation would naturally tend to develop more perfect methods of spinning. Thus, the Jersey wheel would come first, being a natural development from the spindle and whorl. Curious to relate, however, the adoption of the Jersey wheel resulted in an unthought-of development, *viz.*, spindle draft; that is to say, an extension of the sliver during twisting. In view of the present tendency towards mule spinning, this idea should be very carefully considered by worsted spinners, since for very short fibred materials it is the process *par excellence*, although, curious to relate, absolutely useless for long fibred materials. The method of spinning on this wheel would naturally be intermittent, *viz.*:—

1. Drafting with the necessary drafting twist.
2. Adding the necessary twist.
3. Winding on.

FIG. 10.—PRIMITIVE HAND LOOM.

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The unavoidable waste of time, no doubt, set spinners thinking, and the result was the Flax wheel. This wheel simply allows the continuous twisting and winding up of a sliver, which must be previously made by hand. Thus there is little or no spindle draft, but a great advantage is obtained in the continuous action of the wheel. The ease with which materials can be manipulated on this wheel is demonstrated by the fact that a double spindle wheel was in use in the later days of the "domestic" period. Bearing in mind present-day developments, it is interesting to note that the introduction of spindle draft into this method of spinning was advocated early in the eighteenth century, this being effected by the increased speed of the bobbin, as compared with the delivery from the flyer. This spindle draft, however, is not worthy of the name of spindle draft as compared with that effected on the Jersey wheel or on the mule. Worsted spinners should thoroughly realise this point.

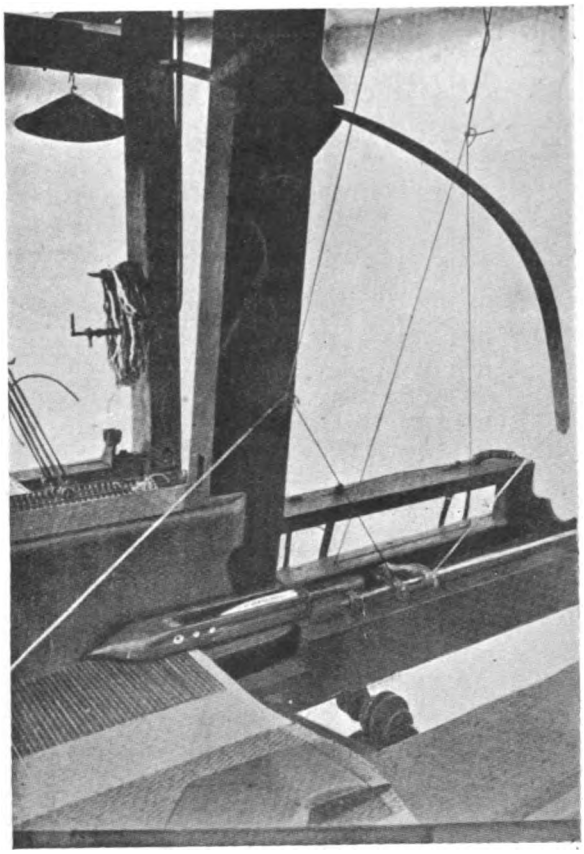

FIG. 11.—HAND LOOM, LATER FORM, WITH KAY'S "FLY SHUTTLE."

DESCRIPTION OF HAND WEAVING.

The hand loom was of a very peculiar construction, consisting of a simple framework with the warp beam acting as back rest and a cloth beam acting as front rest, simple heald-shafts worked by treadles, with the width of the cloth limited by the capacity of the weaver to throw the shuttle through the shed by hand. It is interesting to note that up to the end of the eighteenth century the idea of sizing a warp on the beam had never been suggested, the warp being sized in lengths after the beam was placed in the loom.

A thorough comprehension of these primitive methods, let us again note, is most important. With the elaborate machines at present in use, there must be a marked tendency to think in terms of the machine, and not of the fibre; whereas for good workmanship, the fibre must be the all in all.

It will be noticed that List No. 3 brings us to what may be termed the Cartwright period, *viz.*, from about 1780 to 1820. Before passing to the consideration of this period, however, let us turn to our special subject, "Combing," and study in detail the conditions under which the art was practised prior to the introduction of the machine comb.

These conditions will be described and illustrated in the next article.

LIST NO. I.

Evolution of Industrial Conditions.

The Patriarchal or Family Age.
Village Communities.
Despotism.
Tribal System.
Slavery and Serfdom.
Hereditary Trades and Caste.
Feudal System.
State-regulated Industry.
Free Industry, or the *Laisser Faire* Principle.
Trusts and Combinations (*i.e.*, Self-Regulating Industry).

LIST NO. II.

Previous to the Factory System.

ROMAN PERIOD:

England linked to the Continent.

ANGLO-SAXON PERIOD:

Decline of Industry — Some Continental Trade.

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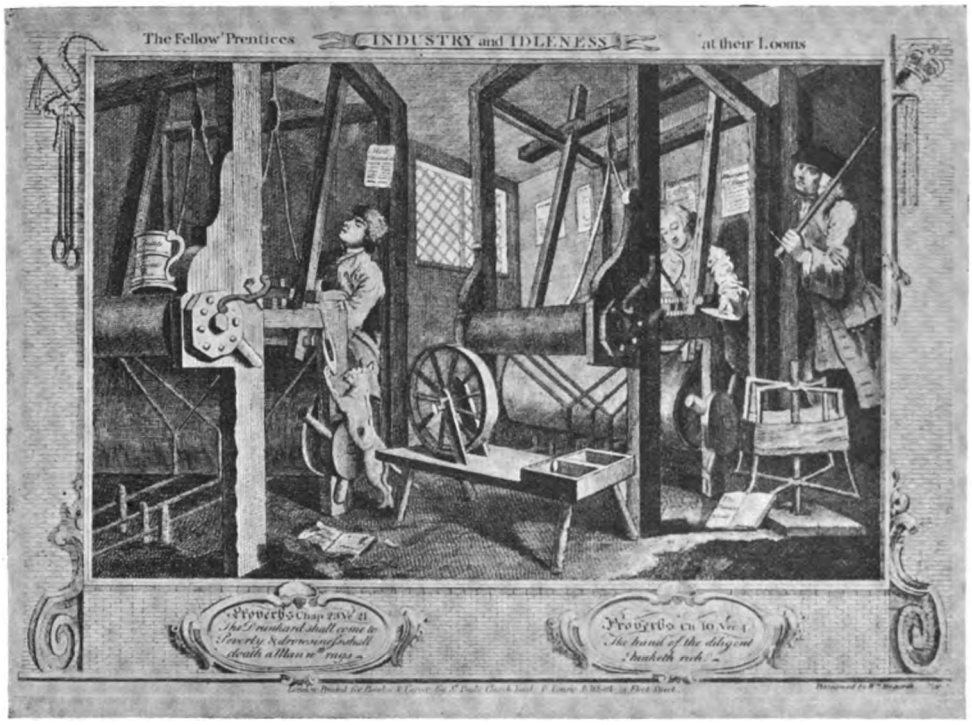

FIG. 12.—HOGARTH'S "IDLE AND INDUSTRIOUS APPRENTICES."

NORMAN PERIOD:

Organisation of English Labour.

England linked to the Continent.
Rise of Towns. Granting of Charters.
Development of Merchant and Craft Guilds.
Rise of Apprenticeship System.
Rise of Wage-earning Class.

Introduction of Foreign Skill.

9/10 of English Wool to Flanders.
English Cloths finished in the Netherlands.
Flemish Immigration (1100 to 1300).
Wealth of Norfolk, 1341.
England a Sheep Farming and Wool Growing Country.

Development of an Industrial System.

Staple Towns. Frauds and Adulteration.
Legal Restrictions on Manufacturers.
Growth of Industrial Villages.
Apprenticeship System basis of Factory System.

TUDOR PERIOD (OR THE RENAISSANCE):

Influences leading up to the Factory System.

Fairs. Visit of Venetian Fleet. Foreign Trade.
Influence of Reformation Conflict.
Influence of Continental Disturbances.
Decay of Antwerp. Rise of London.
Immigration of Flemings and French.
Commercial Wars and Companies.
The Small Manufacturer, probably manufacturing for export.
Commencement of Movement towards the Coalfields of the North.
The Epoch of the Great Inventions.

LIST NO. III.

Development of the Factory System.

(*a*) DEVELOPMENT OF MECHANICAL METHODS OF MANUFACTURE.

Distaff, Hand Cards, Hand Combs, Jersey Wheel, Flax Wheel, Hand Loom.

1589	William Lee:	Stocking Frame.
1650	M. de Gennes:	Power Loom.
1738	John Kay:	Fly Shuttle.
	Robert Kay:	Drop Box.
1738	Lewis Paul John Wyatt:	} Drawing by Rollers. (Ass Power.)
1748	Lewis Paul:	Roller Card.
1750	M. Vaucanson:	Swivel Loom.
1758–59	J. Strutt:	Rib Hosiery Frame.
1764	Jas. Hargreaves:	Spinning Jenny.
1769	R. Arkwright:	Water Frame.
1772	John Lees:	Improved Card.
1779	S. Crompton:	Mule.
1785	E. Cartwright:	First Power Loom.
1789	E. Cartwright:	Wool Comb.
1789	Jas. Watt:	Steam Engine.
1790	E. Cartwright:	Wool Comb, etc.
1790	Jas. Kelly:	Power Mule.
1792	E. Cartwright:	Wool Comb, etc.
1797	E. Cartwright:	Steam Engine.
1803	Johnson:	Warp Dressing Frame.
1804	J. M. Jacquard:	Jacquard Loom.

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1813 Horrocks: Power Loom.
1823 to 1830 Heilmann: Jordain: Risler and Dixon: Sharp and Roberts: Power Looms.
Whitehead: Piecening Machine.

(*b*) Development of Organisation Culminating in the Factory System.

1545 Principle of Interest admitted.
16th Century. Silk Mills at Bologna.
1609 Bank of Amsterdam.

Up to 1690.—Entirely Domestic.

1610 Water-power suggested for spinning.
17th Century. Child Labour (6 years).
German Spinning Schools (girls).

Up to 1730.—Combined Home, Warehouse and Mill.

1718 Lombe's Silk Mill.
(King's influence and power.)

Up to 1780.—Development of Domestic Industries. From Pack Horses to Waggons. Turnpike Roads. Riders for Orders.

1738 Wyatt and Paul's Mill driven by two asses.
1750 to 1757 First Woollen Factory: in Workhouse.
1757 Water-power fully employed.

After 1780.—Partners in London and on Continent. Agents, Factors and Brokers established. Market Days.

1784 First Worsted Factory.
1786 Cartwright employs Steam Engine.

(*c*) Development of Markets.

Prior to 1750.

Virginia. Hudson Bay Territory.
West Indies. Newfoundland.
Gibraltar.

Prior to 1800.

India. Florida.
Canada. Australia.
Ceylon.

Prior to 1850.

Cape Colony. British Guiana.
Natal. Tasmania.
New Zealand. Mauritius.
Malta.

After 1850.

Opening up of China. Opening up of Japan.
Opening up of Africa, etc.

(*To be continued.*)

THEORY OF STRUCTURAL DESIGN.

Part VIII.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

Radii of Gyration.

IN this issue I propose to show how the precise meaning of radii of gyration for beams and columns may be comprehended without a previous knowledge of dynamics. The usual method is based upon dynamical analogies which only tend to mislead and to mystify the majority of those engaged solely in the theory or practice of structural design.

As a first step, let us find the geometrical moment of inertia, or the second moment for the girder represented in Fig. 40.

The second moment for the joist is given in the maker's section books catalogue as 2,380 ins.^{4}. The second moment of the top flange for all practical purposes = 12 ins. × $\frac{5}{8}$ ins. × $12\frac{5}{16}$ ins. × $12\frac{5}{16}$ ins. = 1,140 ins.^{4}, and taking the second moment of the bottom flange at the same value, we have a total second moment of 2,380 + 1,140 + 1,140 = 4,660 ins.^{4}.

From this we should really deduct the second moment of the area taken up by the rivet holes.

The mean thickness through the flanges, $\frac{5}{8} + \frac{7}{8} = 1\frac{1}{2}$ ins. The rivet will be about $\frac{3}{3}$ in. diameter, and the rivet hole will be drilled out to about $\frac{13}{16}$ ins. diameter. The area lost = 1·22 square inches. The leverage arm is about 12 ins., and the second moment is about 1·22 × 144 = 176 ins.^{4}.

As the rivets in each flange are placed zig-zag, there will only be two rivets seen in any cross section; and the second moment lost through rivet space is thus 352 ins.^{4}. The net total of the second moment is thus 4,660 − 352 = 4,308 ins.^{4}.

The 4,308 is no more than an approxi-

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mation; but it is within a half of one per cent. of the true value, as calculated by more laborious and intricate methods.

It frequently simplifies a calculation if we may consider any complex section as being replaced by an equal area formed by two narrow strips, parallel to the neutral axis, and in such a position as will preserve the value of the second moment of the original section.

When the second moment of the two strips has the same value as the second moment of the original section, then the distance between the neutral axis and the centre-line of either strip may be spoken of as the radius of equivalence, or the effective radius.

Take, for example, the two rectangles shown by dotted lines in Fig. 40. The area of each strip is 21 square ins., since the net area of the original section, including joist and flanges, but exclusive of rivet holes = 42 square ins. The effective radius as given on the sketch is 10·13 inches. The second moment of each strip is $21 \times 10{\cdot}13 \times 10{\cdot}13 = 2{,}154$, and the second moment for the two is 4,308.

It will be seen that this 4,308 is equal to the second moment of the original section. We have in the equality of these figures a proof of the correctness of the given radius, or leverage arm. The next step is to obtain a general rule for finding this effective distance, or radius of equivalence.

Let A [square inches] = The area of the original, simple or complex section of any shape whatsoever.

Let $\frac{A}{2}$ [square inches] = The area of each of the two imaginary strips.

Let r [inches] = The distance of each strip from the neutral axis = the radius of equivalence.

Let I [inches^4] = The second moment of the original cross-section, in ins.^{2} × ins.^{2}.

The second moment, or the value of I for one strip $= \frac{A}{2} r^2$.

The total value of I for two strips $= 2 \frac{A}{2} r^2 = A r^2$.

By the definition we know that $A r^2 = I$.

If we divide both sides of this equation by A, and take the square root of each side we have

$$r = \sqrt{\frac{I}{A}} \qquad \text{[Equation XXX.]}$$

If the student has followed the central idea underlying the previous paragraphs, he may, perhaps, remember it better by compressing it into the following form. The effective radius, or the radius of equivalence, is that distance on either side of the neutral axis, at which each half of the cross-sectional area may be assumed to be acting, so as to maintain the original value of the second moment of the section.

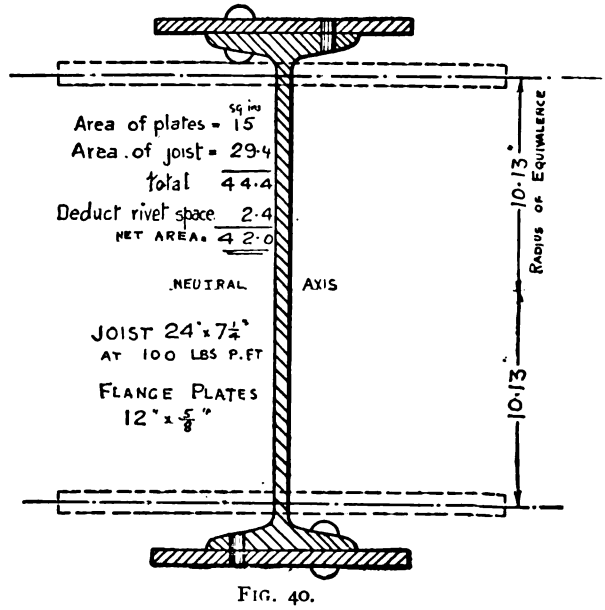

FIG. 40.

If the girder in Fig. 40 be kept in its normal position, but subjected to horizontal pressure, such, for instance, as the wind pressure in a gable frame, then the neutral axis will be vertical, and will be co-incident with the centre-line of the web. For the neutral axis in this position, the value of I will only be 229 ins.^{4}, and the radius of equivalence will be

$$\sqrt{\frac{229}{42}} = 2{\cdot}34 \text{ ins.}$$

and $\frac{\text{least diameter}}{\text{least radius of equivalence}} = \frac{12}{2{\cdot}34} = 5{\cdot}15.$

If the neutral axis were inclined at 45° to the web the value of r would lie somewhere between 2·34 ins. and 10·13 ins.

The practical necessity of finding r with

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respect to this inclined axis rarely, if ever, occurs; and it is only mentioned here to emphasise the fact that we have a different value of r for every inclination of the neutral axis; and to justify the terms "least" and "greatest" radius of equivalence, applied to the two values we have worked out in detail.

By an examination of equation XXX., the student will observe that whenever the second moment of an area occurs in a problem, then the value of the square of the radius of equivalence is involved.

It is chiefly in column formulæ that we need the value of r, for the strength of a column depends among other factors upon the square of the ratio of the length to the effective radius of the column.

It is easy to show, however, that this ratio is not peculiar to the strength of columns, but lies hidden in the ordinary beam formula. For instance, let

w = the load in tons per inch run of beam.

l = length of beam in inches.

f = maximum stress on extreme fibres in tons per square inch.

y = distance between neutral axis and extreme fibres in inches.

$$\frac{w\,l^2}{8} = \mathrm{I}\frac{f}{y}$$

but since $\mathrm{I} = \mathrm{A}r^2$

$$\frac{w\,l^2}{8} = \frac{f}{y}\,\mathrm{A}\,r^2.$$

If we multiply both sides by 8 and divide both sides by l^2 we obtain:

$$w = \frac{8f\mathrm{A}}{y} \times \frac{r^2}{l^2}$$

$$= \frac{8f\mathrm{A}}{y} \div \frac{l^2}{r^2}$$

$$= f \times \frac{8\,\mathrm{A}}{y} \div \left(\frac{l}{r}\right)^2 \quad \text{Equation XXXI.}$$

Now the plain meaning of equation XXXI. is, that the safe load on a beam depends upon three factors; one a stress factor, one an area or section factor, and the last is the square of the ratio of length to radius of equivalence.

Equation XXXI. is never used in the routine of business because the equation $\frac{w\,l^2}{8} = \mathrm{I}\frac{f}{y}$ is simpler. I only give the lengthier equation because it helps to the understanding of all column formulæ. The distance r which we have been discussing is what the text-books persist in calling radius of gyration, although it is not strictly and literally a radius, and had nothing whatever to do with gyration or whirling round.

The term, *radius of gyration*, is more correctly applied to the effective radius of revolution of the earth, or a fly-wheel, or a gyroscope.

It is, perhaps, undesirable to employ the same term for two distinct ideas, yet I must admit that I do not see why a student should be misled by a name which is more or less distinctive, but not descriptive. The student is not misled in other cases. For instance, an atom is literally that which is too minute to be divided, but this does not prevent us talking glibly of the breaking up of atoms into their component corpuscles. Even such common terms as pen-knife and nom-de-plume have lost their literal meaning, for both terms carry back to the days of the quill. However, the fact still remains that the term, radius of gyration, does mislead students, and in some instances the text-books are to blame for the misconceptions which arise. For example, in an otherwise admirable book on steel columns, I find the effective radius or geometrical radius of gyration defined as follows: "Looking upon the cross-section of a stanchion as a thin plane rotating about an axis passing through its centre, the radius of gyration would be measured from the axis to that point at which, if the whole mass were collected, the accumulated work per revolution would remain the same."

Such a definition obviously demands knowledge of a science not usually studied, in these days of specialisation, by those who are engaged solely in structural work.

It would be futile to describe the appearance of nitrate of soda by likening it to snow, when speaking to a person who had never seen either; and for similar reasons I deny the general utility of explaining the structural radius of gyration by reference to the dynamical radius of the same name.

(*To be continued.*)

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REVIEWS.

Radio-active Substances. By Mme. Sklodowska Curie. Thesis presented to the Faculté des Sciences de Paris. Reprinted from the *Chemical News*. Second Edition. pp. 94. (London: *Chemical News* Office, 1904.) Price 2s. net.

Mme. Curie's researches on radium have deservedly gained a world-wide popularity; the publication of a translation of Mme. Curie's celebrated thesis, embodying the results of her researches, will be warmly welcomed by all interested in radio-activity. The thesis is divided into four chapters and an introduction. The first chapter deals with the general problem of radio-activity, and contains a description of the apparatus used by the authoress. Details of the method of research are given in Chapter II. The characteristics of the radiation from radio-active substances are described in Chapter III. The fourth and last chapter is devoted to a discussion of induced radio-activity. A detailed account of the contents of the thesis would occupy more space than can here be spared; those interested in the subject are referred to the original, which is now placed within their reach at a moderate cost. It may prove interesting, however, to give a short description of the method of preparation of radium and other radio-active substances from pitchblende. This expensive ore is mixed at Joachimsthal, in Bohemia. The crushed ore is roasted with sodium carbonate and then washed, first with warm water and afterwards with dilute sulphuric acid. The solution contains the uranium for which the pitchblende was originally mined. The residue is boiled in a strong solution of sodium carbonate; the insoluble portion contains the sulphates of lead and calcium, silica, alumina, and iron oxide; in addition, it contains nearly all the metals (including copper, bismuth, zinc, cobalt, manganese, nickel, vanadium, antimony, thallium, rare earths, niobium, tantalum, arsenic, barium, etc.), in greater or less abundance. Radium occurs in this mixture as a sulphate, and is the least soluble sulphate present. The mixture is treated with a boiling concentrated solution of caustic soda; the SO_4 in combination with the lead, aluminium, and calcium for the most part reacts with the caustic soda, forming sodium sulphate, and is removed by repeated washings with water. The alkaline solution at the same time removes lead, silicon, and aluminium. The insoluble portion is next treated with hydrochloric acid, which disintegrates the material and dissolves most of it. Polonium may be precipitated from the solution by sulphuretted hydrogen; the remaining solution is oxidised, and on addition of ammonia actinium is thrown down with the hydrates. Radium remains in the portion insoluble in HCl. This portion is washed with water, and treated with a boiling Na_2CO_3 solution, which converts the radium, barium, and other substances into carbonates. These are washed and treated with a dilute HCl solution free from H_2SO_4; the solution (containing, amongst other substances, radium, polonium, and actinium), is filtered and precipitated with dilute H_2SO_4. The precipitate consists of the sulphates of barium, radium, calcium, lead, and iron, and traces of actinium. From one ton of residue 10 to 20 kilograms of the crude sulphates are obtained. These are next boiled with sodium carbonate, and subsequently converted into chlorides. The solution is treated with H_2S, which precipitates polonium; after filtering it is oxidised with chlorine and precipitated with pure ammonia. The precipitate is very active, owing to the presence of actinium. The filtered solution is next treated with Na_2CO_3; the precipitated carbonates of the alkaline earths are washed and converted into chlorides, which are evaporated to dryness and washed with pure HCl. Calcium dissolves entirely, while the chlorides of barium and radium remain insoluble. The latter chlorides are then separated by fractionation: (1) by crystallisation in pure water; and (2) by crystallisation in dilute HCl. The chloride of radium is less soluble than that of barium.

In conclusion, we may remark that the presence of helium in pitchblende suggested to Professor Rutherford that radium is being converted into that gas; the presence of so many other metals in the mineral seems to suggest, either that many of these are produced as decomposition products of radium, or that all are decomposition products of some other unknown substance, of which the mineral at first mainly consisted.

Electric Motors: Continuous Current Motors and Induction Motors, their Theory and Construction. By Henry M. Hobart, M.I.E.E., Mem. A.I.E.E. pp. x. + 458, with 480 Illustrations. (London: Whittaker & Co., 1904.) Price 12s. 6d. net.

The rapid development of schemes for power distribution has led to great improvements in the electric motor; moreover, the accumulation of valuable information relative to the working of different types of motors has rendered it possible to make a fairly exact comparison between the advantages of continuous current motors and alternating current motors. On the whole, it appears that the continuous current motor is the more generally useful. At the time of the introduction of the polyphase motor, much was hoped from it on the score of the possible avoidance of all moving contacts, combined with the economy of transmitting power at high voltage, and transforming to low voltage by

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means of apparatus without moving parts. But the troubles with commutation, which at first constituted the chief drawback to the use of the continuous current motor, have now been overcome; on the other hand, it has been found necessary to introduce moving contacts into the design of induction motors, in order to obtain a sufficient starting torque. It may be remarked that one of the most promising lines of development of the single-phase motor involves the use of a commutator. In certain cases the induction motor may be used with advantage; but it can no longer be maintained that in all circumstances the use of continuous current motors should be discouraged on account of their greater complexity.

In order to form trustworthy conclusions on this subject, it is necessary to digest an enormous amount of numerical data obtained by electrical engineers in all parts of the globe. This useful task has been conscientiously performed by Mr. Hobart; and for this alone every electrical engineer will feel grateful. Many text-books on dynamo design proceed on lines which, though convincing enough, are far from comprehensive. Students are often surprised, on entering the works of an engineering firm after concluding their college career, to find that so much of the knowledge they have acquired is left out of account in the practical design of dynamo-electric machinery on a commercial scale. This discrepancy between theory and practice is not due to any inherent error in the theory; it is a consequence of the restrictions generally imposed on the theoretical treatment of the subject, the primary practical considerations of cost and economy being given insufficient weight. To give adequate weight to these considerations, of course, leads to additional complexity and difficulty in the study of the subject; but since an engineer must design his machines on economical principles, the study of these cannot be dispensed with. The salient characteristic of Mr. Hobart's book is the continual appeal to the work carried out by large engineering firms; and this characteristic adds a value to the book which is scarcely possessed by any other work on electrical engineering. It must not be concluded, however, that Mr. Hobart has merely tabulated data concerning existing methods, and added nothing thereto; in many cases Mr. Hobart draws novel and interesting conclusions from the information he has collected. There is no doubt that this book will usefully supplement the treatises of Kapp, Thompson, Arnold, Hawkins and Wallis, and others.

Elementary Manual on Steam and the Steam Engine. Specially arranged for the use of first-year Board of Education, South Kensington, City and Guilds of London Institute, Colonial and other Engineering Students. By Andrew Jamieson, M.Inst.C.E. Tenth Edition, revised. pp. xii.+330. (London: Chas. Griffin & Co., 1904.) Price 3s. 6d.

This book is too well known to need detailed criticism here. The chief alterations introduced in the present edition are: The addition of a coloured working drawing of a modern Lancashire boiler as frontispiece; the inclusion of details of electrical pyrometers, the latest form of steam engine indicators, the 1902 piston and connecting rods for the L.C.C. Tramway Power Station engines, the condensing plant for the Glasgow Tramway Power Station, and some details of the latest steam turbines. All the most important elementary questions set at the May examinations of the Board of Education (late Science and Art Department) for the last dozen years are given.

THE September Number of TECHNICS will contain an Article by Sir OLIVER LODGE, F.R.S., dealing with a novel development of "THE ELECTRON THEORY." Modern researches on radio-activity have laid a foundation for a physical theory of chemical affinity, which Sir OLIVER LODGE has developed. The same Number of TECHNICS will contain a continuation of Mr. LANCHESTER'S Article, dealing with "THE DEVELOPMENT OF THE MOTOR CAR"; a continuation of Professor FLEMING'S Article on "ELECTRIC WAVES"; an Article by J. ODDY, Barrister-at-Law, on the "RIGHT TO LIGHT," as deduced from the decision of the Law Lords in the case of Colls v. The Home and Colonial Stores; together with other articles of scientific and technical interest.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the* 10*th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

NITROSO.—In Roscoe and Schorlemmer's treatise on chemistry, vol. ii., p. 1015, directions are given for making potassium-iron heptanitroso-sulphide. I have failed to obtain the crystals of a diamond lustre, but get instead a sooty precipitate, evidently iron sulphide. Would you please give me fuller working directions for making the nitroso-sulphide compound in fairly large quantities.

Ten grains of potassium hydroxide is dissolved in 90 c.c. of water, and converted by a stream of hydrogen-sulphide into the sulphydrate (K H S). The resulting liquid is added to a boiling solution of 8 grams of sodium-nitrite in 90 c.c. of water. A second solution, containing 41 grams of crystallised ferrous sulphate in 280 c.c. of water, is prepared, and acidulated with one drop of dilute sulphuric acid; this is then allowed to flow gradually into the former solution, which should be boiling, the whole being well stirred in the process. The mixture is kept hot until a distinct greenish-red precipitate begins to form, when it is filtered quickly through a fluted filter-paper, allowed to cool, and then mixed with a few c.c. of dilute potassium hydroxide. After standing some time a salt separates, and at the end of two days this may be removed, and crystallised after dissolving it in water at 70° C. containing a very little potassium hydroxide. After 48 hours the crystals of potassium iron heptanitroso-sulphide may be filtered off and dried in a vacuum.

INTEGRAL.—Find the value of

$$\int \left(\frac{a+x}{x}\right)^{\frac{1}{2}} dx.$$

Let $x = z^2$ $\therefore dx = 2z\,dz = 2x^{\frac{1}{2}}\,dz$

$$\therefore dx/x^{\frac{1}{2}} = 2\,dz$$

$$\therefore \int (a+x)^{\frac{1}{2}} \frac{dx}{x^{\frac{1}{2}}} = 2\int (a+z^2)^{\frac{1}{2}}\,dz$$

This integral has now been brought to a standard form, of which the solution is

$$z(z^2+a)^{\frac{1}{2}} + a\log_{\epsilon}\left\{z + \sqrt{z^2+a}\right\}$$

$$= \sqrt{(ax+x^2)} + a\log_{\epsilon}\left\{\sqrt{x} + \sqrt{x+a}\right\}$$

RECALESCENCE.—What is meant by recalescence with regard to iron or steel? Describe the changes in magnetic properties which accompany recalescence in these metals.

If a piece of steel or iron wire, raised to a white heat, is observed in a dark room as it cools, it will be noticed that the colour of the light emitted becomes redder and fainter as cooling proceeds, until at a certain point luminosity vanishes. Shortly afterwards the iron once more becomes luminous. It is supposed that an atomic re-arrangement occurs which involves a liberation of heat; this is termed *recalescence*, or automatic re-heating. The most marked recalescence in iron occurs at 600° C.; at this temperature no magnetic change occurs in the iron. At 785° C. another definite recalescence occurs, which is associated with magnetic changes. Above this temperature iron or steel is non-magnetic. If iron is gradually heated, the permeability for a small magnetising force (say 0·3 c.g.s. units) steadily increases until a maximum is reached just below the 785° C. When the latter temperature is reached the iron suddenly loses its magnetic properties. Just below the temperature of recalescence, the hysteresis losses in iron are reduced to a minimum.

MÉRNÖK.—Is there any method of solving the following simultaneous equations without involving a complete equation of the fourth degree?

$$x + \sqrt{y} = a$$

$$y + \sqrt{x} = b.$$

These equations reduce to a biquadratic wanting the cubed term, *viz.*,

$$(a-x)^4 - 2b(a-x)^2 + (a-x) + b^2 - a = 0$$

in which $a - x$ is looked on as the unknown.

In the special case in which $b^2 = a$ we see that $x = a$ and $y = 0$.

If the numerical values of a and b are known, then the half parabolas represented by the two equations can be plotted and their point of intersection (if there be one) determined.

MANGANESE ALLOYS.—Can you inform me of any works, either English or American, dealing with manganese alloys such as manganese bronze, for casting purposes or rolling; also a work on chill casting?

So far as our knowledge goes, there is no work in English devoted to manganese bronze or to chill casting. Many of the works dealing with alloys treat this bronze very briefly; for instance, Roberts Austen's "Introduction to the Study of Metallurgy" has but one reference, (page 132).

Hiorn's "Mixed Metals" (pages 201—212) is

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more explicit, but I question whether sufficient detail is given to prove satisfactory. Several papers on alloys which briefly touch on manganese bronze are published. Of these, the following occur to us at the moment :—

"*Alloys*": E. Storey. (Manchester Association of Engineers, 1903.)

"*Brasses and Bronzes*": Longmuir. (Sheffield Society of Engineers and Metallurgists. March, 1900); and a more recent one in the *Giesserei Zeitung* of March 15th, 1904.

Manganese alloys, in ordinary brass foundry practice, are used as deoxidisers, and many commercial manganese bronzes contain only traces of manganese.

It is probable that the scarcity of literature is due, in this country at any rate, to the fact that manganese bronzes are manufactured by comparatively few firms. With regard to chill casting, here again no definite work may be had, and information can only be obtained by reference to the files of various technical journals.

POROUS PLUG EXPERIMENT. — Show how the rise in temperature when a gas is forced through a porous plug may, by use of the Second Law of Thermodynamics, be applied to determine the absolute zero.—*Board of Education* (*Heat*), *Honours*, 1904.

The solution of this problem involves another, which it will be convenient to deal with first. We shall therefore first prove that *if a volume v of any substance is compressed isothermally, the pressure rising from p to $p + dp$, then the heat given out during the operation is equal to*

$$\frac{\theta a v \cdot dp}{J}$$

where—

θ = the initial temperature (absolute) of the substance

a = the dilatability (increase in volume per unit volume at constant pressure for a rise of 1° in temperature) of the substance.

J = the mechanical equivalent of unit quantity of heat.

Let A B, H D, Fig. 1, be the isothermals of the substance for absolute temperatures θ and $(\theta + d\theta)$. Let A be the initial, and B the final state of the substance; pressures being measured vertically upwards, and volumes from left to right. Draw the adiabatics A C and B D, cutting the θ isothermal in A and B, and the $(\theta + d\theta)$ isothermal in C and D. Then if a quantity of heat $(Q + dQ)$ is absorbed when the substance expands isothermally from D to C, and a quantity of heat Q is given up when the substance is compressed isothermally from A to B, we have, by the Carnot's theorem,

$$\frac{(Q + dQ) - Q}{Q} = \frac{(\theta + d\theta) - \theta}{\theta}$$

$$\therefore \frac{dQ}{Q} = \frac{d\theta}{\theta}$$

$$\text{and } Q = \theta \frac{dQ}{d\theta}$$

Q is, of course, the quantity which we wish to determine. By the First Law of Thermodynamics, dQ is the heat equivalent of the area D C A B. Thus,

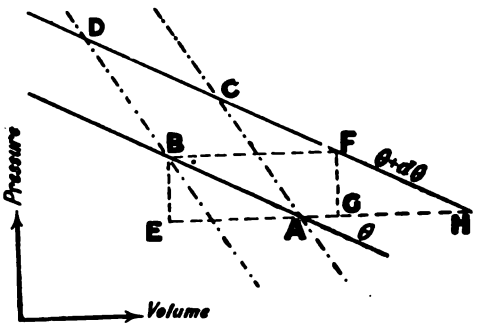

FIG. 1.—POROUS PLUG.

$$Q = \frac{\theta \times \text{area D C A B}}{J\, d\theta} \quad \ldots\ldots \quad (1)$$

Through A and B draw the constant-pressure lines E A H and B F, cutting the $(\theta + d\theta)$ isothermal in H and F respectively. Through B and F draw the constant volume lines B E and F G, cutting E H in E and G respectively. Then if the two isothermals are supposed to be very near to each other, they will be approximately parallel; for similar reasons the two adiabates will be approximately parallel, and the figures D C A B, B F H A, will be parallelograms standing on the common base B A, and lying between the same parallels B A and D H. Therefore

$$\text{area D C A B} = \text{area B F H A}.$$

But the parallelograms B F H A, B F G E, stand on the common base B F, and lie between the parallels B F and E H. Thus

$$\text{area B F H A} = \text{area B F G E};$$

$$\therefore \text{area D C A B} = \text{area B F G E},$$

and (1) becomes

$$Q = \frac{\theta \times \text{area B F G E}}{J\, d\theta} \quad \ldots\ldots \quad (2)$$

Now area B F G E = B F × B E. The line B E represents the difference in pressure dp between the points A and B. The line B F represents the increase in volume which occurs when the substance at B is heated at constant pressure from θ to $(\theta + d\theta)$. Thus B F = $v\, a\, d\theta$, where a is the dilatability of the substance at constant pressure. Substituting in (2), we obtain

$$Q = \frac{\theta \times v\, a\, d\theta \times dp}{J\, d\theta} = \frac{\theta a v \cdot dp}{J}$$

We are now in a position to attack the main question at issue. The experimental details of Joule and Kelvin's porous plug experiment need not be given here; they may be found in textbooks on Heat, such as Edser's *Heat for Advanced Students* (Macmillan & Co.), pp. 380-385.

It will here be assumed that the gas is forced by the piston C through the plug E (Fig. 2) from left to right: the pressure to the left of the plug being $(p + dp)$, while that to the right of the plug is p.

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1. Let us suppose that the piston D is initially close up against the diaphragm E, and that as it moves to the position D shown in Fig. 2, one gram of gas is forced through the plug. Let the rise in temperature of the gas be equal to $d\theta$ (if the gas is cooled, we must prefix a negative sign to $d\theta$). Let the initial volume of the gram of gas be $(v - dv)$; and let its volume, after being forced through the plug, be v. Then the work done *by the piston* C in forcing the gas through the plug must be equal to

$$(p + dp)\ (v - dv) \text{ ergs},$$

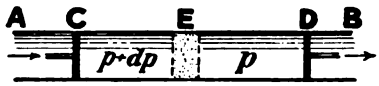

FIG. 2.—POROUS PLUG.

if p is measured in dynes per square cm., and v is measured in cubic centimeters. The work done *by the gas*, in forcing the piston D outwards, must be pv ergs. It is supposed that no heat is allowed to enter or leave the gas during this operation.

In Fig. 3, the point A corresponds to the initial, and the point B to the final state of the gas. Expansion has occurred along the line A B. Let us suppose that the piston C has now reached the porous plug E, and that it remains in this position during the subsequent operations, so that no gas can be forced from right to left through the plug.

2. Let us now cool the gas at constant pressure, till its temperature reaches θ. In this operation the piston D (Fig. 2) moves inwards, the change in the state of the gas being represented by the horizontal straight line B C in Fig. 3. The heat given up by the gas is equal to $1 \times \sigma_p \times d\theta = \sigma_p\, d\theta$ heat units.

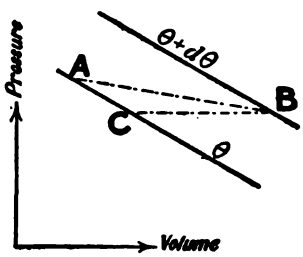

FIG. 3.—POROUS PLUG.

3. In order to bring the gas back to its original state, we must now compress it isothermally from C to A (Fig. 3). In this operation, since the pressure of the gas rises from p to $p + dp$, the heat given out is equal to

$$\frac{\theta\, a\, v \cdot dp}{J}$$

In the second and third operations, the volume of the gas has been diminished by dv, the pressure being approximately equal to p. Thus the work performed on the gas during these operations is equal to $p\,dv$. The gas has now been brought back to its original condition, so that its internal energy is the same as before it was forced through the plug. The external work done by the gas during the cycle is equal to the area A B C; if dp is small, this area may be neglected. Then we must have

(Work done *on* gas) − (work done *by* gas) = mechanical equivalent of heat given out by gas;

$$\therefore \{(p + dp)\ (v - dv) + p\,dv\} - pv = J\left\{\sigma_p\, d\theta + \frac{\theta\, a\, v\, dp}{J}\right\}$$

Simplifying, and neglecting the product of the small quantities dp and dv, we obtain

$$v\,dp = J\,\sigma_p\, d\theta + \theta\, a\, v\, dp$$

$$d\theta = \frac{v\,dp(1 - a\theta)}{J\sigma_p}.$$

According to the experiments of Regnault, the isothermals for air between moderate limits of temperature are given by

$$pv = p_0 v_0(1 + \beta t),$$

where t is the centigrade temperature according to the air thermometer, β is equal to 1/273 very nearly, and p_0 and v_0 represent the pressure and volume at 0° C.;

$$\therefore \quad v = \frac{p_0 v_0}{p}(1 + \beta t),$$

and
$$d\theta = \frac{p_0 v_0}{J\sigma_p}(1 + \beta t)(1 - a\theta)\frac{dp}{p} \quad . \quad . \quad (3)$$

It now becomes necessary to determine the value of the dilatability a, in terms of the coefficient of expansion at constant pressure β. A quantity of air occupying unit volume at 0° C. occupies a volume $(1 + \beta t)$ at $t°$, and a volume of $\{1 + \beta(t + 1)\}$ at $(t + 1)°$. Therefore increase of volume per degree rise of temperature per unit of volume at $t°$

$$= a = \beta/(1 + \beta t);$$

$$\therefore \quad d\theta = \frac{p_0 v_0}{J\sigma_p}(1 + \beta t)\left\{1 - \frac{\beta}{1 + \beta t}\theta\right\}\frac{dp}{p}$$

$$= \frac{p_0 v_0}{J\sigma_p}\left\{1 + \beta(t - \theta)\right\}\frac{dp}{p} \quad . \quad . \quad (4)$$

In the above investigation it has been assumed that dp, the difference of pressure on opposite sides of the plug, is small. In Joule and Kelvin's experiments the difference of pressure amounted to several atmospheres. To adapt our calculations to these conditions, let us suppose the porous plug to be divided into a great number of thin slices, the difference of pressure on opposite sides of a slice being equal to dp. Then the heating effect produced by forcing the gas through a slice is given by (4); and to find the heating effect produced by forcing the gas through the whole plug we must integrate the right-hand side of (4) between the limits p_1 (high pressure) and p_2 (low pressure). If heating occurs, t and θ will vary for the different slices; but the *change* in t, the centigrade gas thermometer temperature, will differ only very slightly from the change in θ, the absolute temperature, so that we may assume

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$(t - \theta)$ to remain constant. Under these conditions we need only integrate dp/p, which gives us $\log_e(p_1/p_2)$, when the limiting values are substituted. Thus if δ is the total rise of temperature due to forcing the gas through the plug,

$$\delta = \frac{p_0 v_0}{J\sigma_p}\left\{1 + \beta(t - \theta)\right\}\log_e \frac{p_1}{p_2};$$

$$\therefore\ \theta = \frac{1 + \beta t}{\beta} - \frac{J\sigma_p\,\delta}{\beta v_0 p_0(\log_e p_1 - \log_e p_2)} \quad (5)$$

Let us use this result to determine the absolute temperature of melting ice, from data referring to dry air.

In this case $t = 0$.

$\beta = 0{\cdot}0036706$ (Regnault).

$\sigma_p = 0{\cdot}2375$ (Regnault).

$J = 42 \times 10^6$.

From Joule and Kelvin's experiment, when p_2 = two atmospheres, and p_1 = 1 atmosphere, the value of δ for air is $-0{\cdot}263°$.

A gram of air at 0° C., and under a pressure of 760 mm. of mercury, occupies a volume of 773·3 c.c.

$\therefore p_0 v_0 = 1{\cdot}01 \times 10^6$ dynes $\times$ 773·3 c.c.

Substituting these values in (5), we obtain

$$\theta = \frac{1}{0{\cdot}0036706} - \frac{42 \times 10^6 \times 0{\cdot}2375 \times (-0{\cdot}263)}{0{\cdot}00367 \times 1{\cdot}01 \times 10^6 \times 773{\cdot}3 \times 2{\cdot}30 \times 0{\cdot}3010}$$

$$= 272{\cdot}5 + 1{\cdot}3 = 273{\cdot}8.$$

Thus the absolute temperature of melting ice is 273·8°; consequently the absolute zero is 273·8 absolute degrees below the centigrade zero.

MARCHING CURVES.—Each point on a curve marches at a constant speed along a line making a given angle with the normal to the curve at that point. Given the form of the curve at a given instant find the form of the curve after a time t.

Let $t = f(x, y)$ represent the form of the curve at time t, then $t + \delta t = f(\xi, \eta)$ will be the form at time $t + \delta t$, where ξ, η are the co-ordinates of the point which was at x, y at time t.

Hence $$t + \delta t = f(x, y) + (\xi - x)\frac{df}{dx} + (\eta - y)\frac{df}{dy};$$

$$\therefore\ \delta t = (\xi - x)\frac{df}{dx} + (\eta - y)\frac{df}{dy}.$$

If each point moves with constant velocity v along a line making a constant angle a with the instantaneous normal, we have

$$(\xi - x)\frac{df}{dx} + (\eta - y)\frac{df}{dy} = v\cos a\,\delta t\left\{\left(\frac{df}{dx}\right)^2 + \left(\frac{df}{dy}\right)^2\right\}.$$

Thus $$\frac{1}{v^2\cos^2 a} = \left(\frac{df}{dx}\right)^2 + \left(\frac{df}{dy}\right)^2.$$

This is a partial differential equation for the required curves, and is of a well-known type.

The general primitive is obtained by eliminating a between

$$tv\cos a = ax + (1 - a^2)^{\frac{1}{2}}y + \phi(a) \quad . \quad (1)$$

and $$x - \frac{a}{(1 - a^2)^{\frac{1}{2}}}y + \frac{d\phi(a)}{da} = 0 \quad . \quad . \quad (2)$$

where a is an arbitrary constant and ϕ an arbitrary function.

If the curve is given by $\psi(x, y) = 0$ when $t = 0$, the elimination of x and y between

$$a\,x + (1 - a^2)^{\frac{1}{2}}\,y + \phi\,(a) = 0$$

$$x - \frac{a}{(1 - a^2)^{\frac{1}{2}}}\,y + \frac{d\,\phi\,(a)}{d\,a} = 0$$

$$\text{and } \psi\,(x, y) = 0$$

will give an ordinary differential equation to determine the form of ϕ, and having solved this, we obtain the form of the curve at any time from (1) and (2).

This is a simple case of a very general problem which is solved in the standard works on differential equations (Boole, Forsyth), *viz.*, to find the solution of a partial differential equation of the first order in n variables, which shall assume a given form when one of the variables is equal to zero.

It must be evident that when the point moves along the instantaneous tangent, it must remain on the original curve.

TARGET RAFT.—A target raft is constructed of thin wooden blades fixed transversely to two fore-and-aft spars at an angle of about 10° to the horizon (Fig. 1). When the raft is at rest, the water-line is level with the lower surfaces of the fore-and-aft spars. When the raft is towed, the reaction of the water on the blades produces a lifting force which causes the raft to rise bodily. It is found that the resistance offered to the motion of the raft decreases with the velocity at which it is towed; thus a small model, on still water, cannot be hauled by a single man at a speed of five knots, while at ten knots a man can haul it easily. I should be much obliged if you could throw any light on this subject; the behaviour of the raft is not what would be anticipated, since the resistance to motion of a body through a fluid increases with the square of the velocity.

This interesting query recalls a number of classical researches. Scott-Russell found that

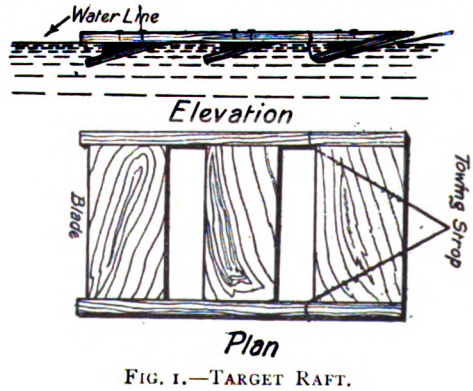

FIG. 1.—TARGET RAFT.

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in order to haul a barge along a canal, a smaller force is required at high than at low speeds. This is due to the fact that the barge produces waves which travel over the surface of the water with a velocity depending on the depth of the canal. When the barge travels at the same speed as the waves, only one wave is formed, which accompanies the barge, so that energy is not used up in continually forming new waves; consequently the towing force is diminished. This explanation, however, will not apply to the target raft, which is towed on the open sea; here the waves are of a different character, their speed depending on their wave length. If waves of a particular length were alone formed, the raft, when travelling at the same speed as these, would require a smaller towing force than at other speeds; but there is no reason to suppose that waves of any particular length are alone formed.

The phenomena described in the query are obviously allied to those observed by Froude in his experiments on the *Ramus* type of ship. This ship had a bottom formed of two inclined planes; at high speeds a lifting force was developed, so that the ship skimmed over the surface. At all speeds, however, the resistance was greater than that of a ship of the ordinary type.

According to Froude, a plane moving on the surface of water is acted upon by two forces: one P, normal to the surface; and another F, parallel to the surface, due to frictional resistance. From Froude's experiments,

$$P = a\,A\,V^2 \sin\theta$$

when a is a coefficient (about 3)

A = area of plane in sq. ft.

V = speed in knots.

θ = angle of inclination of plane to the horizon;

$$\text{also } F = b\,A\,V_1^2$$

where b is a coefficient (about 0·01)

V_1 = speed of the plane in its own direction

$$= V\cos\theta$$

$$\therefore F = b\,A\,V^2\cos^2\theta.$$

The resultant force, R, which opposes the motion of the plane, is found by adding the horizontal components of P and F,

$$R = a\,A\,V^2\sin^2\theta + b\,A\,V^2\cos^3\theta.$$

The value of A, the immersed area of the blades, varies with the speed; let A_5 be its value for 5 knots, and A_{10} its value for 10 knots. Then if R_5 and R_{10} are the opposing forces for 5 and 10 knots respectively, and θ, the inclination of the blades, remains constant,

$$R_5 = 25\,A_5\,(a\sin^2\theta + b\cos^3\theta)$$

$$R_{10} = 100\,A_{10}\,(a\sin^2\theta + b\cos^3\theta)$$

$$\therefore \frac{R_{10}}{R_5} = 4\,\frac{A_{10}}{A_5} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let f_5 and f_{10} be the lifting forces at 5 and 10 knots respectively, and W = weight of raft. If v = volume of blades per unit area, the water displaced at 5 and 10 knots respectively will be equal to $v\,A_5$ and $v\,A_{10}$. Then

$$f_5 = W - v\,A_5 = v\,(A_0 - A_5) \quad . \quad . \quad (2)$$

where A_0 = area of blades immersed when the raft is at rest.

Similarly,

$$f_{10} = v\,(A_0 - A_{10}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The lifting force is found by subtracting the vertical component of R from the vertical component of P; therefore

$$f_5 = 25\,A_5\,(a\sin\theta\cos\theta - b\cos^2\theta\sin\theta)$$
$$= 25\,A_5\,c \text{ (say)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$f_{10} = 100\,A_{10}\,(a\sin\theta\cos\theta - b\cos^2\theta\sin\theta)$$
$$= 100\,A_5\,c \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

From (2) and (4)

$$25\,c\,A_5 = v\,(A_0 - A_5) \quad \therefore A_5 = \frac{v\,A_0}{v + 25\,c}$$

From (3) and (5)

$$A_{10} = \frac{v\,A_0}{v + 100\,c}$$

Substituting in (1), we obtain

$$\frac{R_{10}}{R_5} = 4\,\frac{v + 25\,c}{v + 100\,c} = \frac{4\,v + 100\,c}{v + 100\,c}$$

According to this calculation, the resisting force should be greater at 10 than at 5 knots, which is contrary to experience. The most probable explanation of this discrepancy is that the inclination of the blades varies somewhat with the speed. That this might have been anticipated will be seen from the following reasoning.

It is well known that a flat plate, when moving through a fluid, always tends to set itself broadside on to the direction of motion; this can be observed when a sheet of paper or cardboard falls through the air, or when a penny piece sinks through water.

The reason is as follows. Let us suppose that a disc A B (Fig. 2) is placed in an inclined position across a uniform current of water, flowing from right to left; then the forces acting on the disc will obviously be the same as if the water were stationary, and the disc were moved

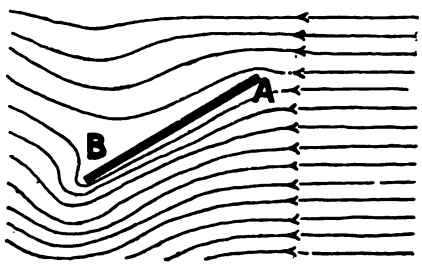

FIG. 2.—TARGET RAFT.

from left to right through it. The lines of flow of the water are indicated by the curved lines; it is apparent that these lines are very much crowded on the right-hand side of the lower edge of the disc, indicating that here the velocity of the water is greater than elsewhere. According to the well-known law that where the velocity is greatest the pressure is least, the pressure from right to left on the disc at B will be less than

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the pressure in the same direction at A; with the consequence that a torque will be produced tending to rotate the disc till it is perpendicular to the direction of the current.

Returning to the target raft, when this is slowly towed through the water, the blades are fully immersed, and the torque called into play will tend to depress the after end of the raft, thus increasing the inclination of the blades to the horizon, and increasing the force which opposes the motion of the raft. At high speeds the torque will act under less favourable conditions, since the two opposite forces must act on the limited area of the blade now immersed, and the arm of the couple is reduced; thus there will be less tendency to depress the after end of the raft, and the force opposing the motion of the raft will be diminished.

There is little doubt that the actions described above actually occur; it may be questioned, however, whether other actions are partly or mainly responsible for the phenomenon in question. We should be pleased to receive further particulars of the experiment, especially with reference to the degree of tilt observed. We would also receive with pleasure communications from those who have conducted similar experiments.

PITCH CURVES (*Cleveland, Ohio*).—**In the accompanying sketch, A represents a rack which meshes with the pinion B and rotates the irregular gear C by means of the shaft O. The gear D is always in mesh with C, and rotates the pointer E by means of the shaft O_1. The curve *abc* is part of a parabola with its axis horizontal. As the curve moves uniformly from right to left (horizontally), the rack A moves vertically, while C and**

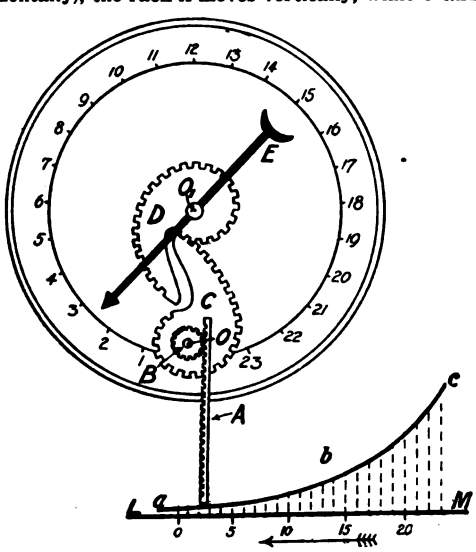

FIG. 1.—PITCH CURVES.

D rotate in opposite senses. It is required to find the equations to the pitch curves of C and D, so that E may rotate uniformly.

In order that the pitch curves may roll on one another, it is necessary that their lengths shall be equal, that OO_1 shall be constant, and that the curves shall have a common tangent at their point of contact. These three conditions are not, however, independent; the first follows from the other two. To express these conditions mathematically:—

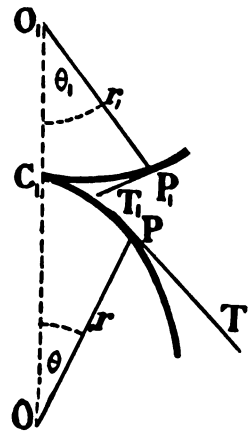

FIG. 2.—PITCH CURVES.

Let C_1 (Fig. 2) be the point of contact when the pointer is at zero, C_1P_1 and C_1P the pitch lines, P and P_1 points which will come in contact when C and D (Fig. 1) have turned through angles θ and θ_1 in opposite senses; P_1T_1 and PT tangents at these points. We see that when P and P_1 are in contact, P_1T_1 and PT must be coincident; hence the angles $O_1P_1T_1$ and OPT are equal. Also $r + r_1 = OO_1 = d$ (say), and the arc C_1P_1 = the arc C_1P.

The tangent of the angle $O_1P_1T_1$ is given by $r_1 d\theta_1/dr_1$ and that of OPT by $-\, rd\theta/dr$.

Hence
$$r_1 \frac{d\theta_1}{dr_1} = -\, r \frac{d\theta}{dr} \quad . \quad . \quad . \quad (1)$$

and
$$r + r_1 = d \quad . \quad . \quad . \quad . \quad (2)$$

From these equations it is easily shown that $C_1P_1 = C_1P$ (unless the tangent is in line with the radius vector).

From (2) $\frac{dr}{dr_1} = -\,1$, and hence from (1),

$$\frac{d\theta_1}{d\theta} = \frac{r}{r_1} \quad . \quad . \quad . \quad . \quad (3)$$

Turning our attention to the parabolic curve *abc*, if we take the point on *abc* corresponding to 0 as the origin of co-ordinates, the equation is of the form

$$(k - y)^2 = 4p(h - x)$$

the axis of y being vertical, and k and h the vertical and horizontal distances of the point in question from the vertex of the parabola. Taking, for simplicity, the radius of B as the unit of length, $\theta = y$; and since θ_1 is to be proportional to x, we may take $x = m\theta_1$, hence

$$(k - \theta)^2 = 4p(h - m\theta_1).$$

Differentiating this, we obtain

$$k - \theta = 2pm \frac{d\theta_1}{d\theta},$$

and hence from (3)

$$k - \theta = 2pm \frac{r}{r_1} = 2pm \frac{r}{d - r},$$

or
$$\frac{d}{r} - 1 = \frac{2pm}{k - \theta} \quad . \quad . \quad (4)$$

Equation (4) gives the polar equation to the pitch line of C.

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It is evident that θ must always be less than k, for if $\theta = k$, r must be zero; compliance with this condition can always be secured by starting with the parabola in a proper position. The curve can easily be plotted when the constants d, p, m, and k are known. These may not be chosen at random, for from the parabolic equation we have

$$k^2 = 4ph;$$

also k must be greater than θ, and since θ may have any value up to 2π, we must take k greater than 2π times the radius of B. Another connection is obtained from $x = m\theta_1$; for when $x = t$ the maximum horizontal travel $\theta_1 = 2\pi$, and hence

$$t = 2\pi m$$

and
$$(k - 2\pi)^2 = 4p(h - t)$$
$$= 4p(h - 2\pi m),$$

which reduces to

$$k - \pi = 2pm.$$

We may therefore give p any convenient value, (say 1, the radius of B), k a value something greater than 2π (say 8), then $h = 16$, and $m = 2{\cdot}43$ approximately. Choosing $d = 6$ (say), we have

$$\frac{6}{r} = 1 + \frac{4{\cdot}86}{8 - \theta} \quad . \quad . \quad . \quad (5)$$

For the equation to D, we have from (4)

$$\frac{r_1}{d - r_1} = \frac{2pm}{2\sqrt{p}\sqrt{h - m\theta_1}}$$

or
$$\frac{d}{r_1} - 1 = \frac{1}{m\sqrt{p}}\sqrt{h - m\theta_1}.$$

J. W. H.—Given a right-angled triangle whose hypotenuse is H (say 50 chains), base x, and altitude y. Enclosed within the triangle (see Fig. 1) is a rectangle whose sides are a (say 10 chains) and b (say 20 chains). It is required to find x and y.

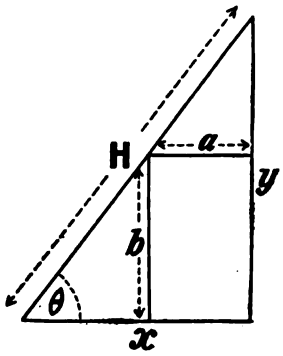

FIG. 1.

The problem is not always a possible one, *i.e.*, given a and b, there are certain limits within which H must lie. These conditions being fulfilled, there are in general two positions for the hypotenuse.

From the figure we have

$$y = \sqrt{H^2 - x^2}$$

and
$$\frac{\sqrt{H^2 - x^2}}{x} = \frac{b}{x - a} \quad . \quad . \quad (1)$$

Squaring out, and arranging in powers of x, we obtain the equation

$$x^4 - 2ax^3 \quad x^2(H^2 - a^2 - b^2) + 2aH^2x$$
$$- a^2H^2 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This equation has four roots, but all of these will not necessarily satisfy (1).

(By Descartes's rule we see that (2) cannot have more than three positive roots.)

Substituting for a, b and H, 1, 2 and 5, we obtain

$$x^4 - 2x^3 - 20x^2 + 50x - 25 = 0 \quad . \quad . \quad (3)$$

By plotting the graph of the left-hand side of (3), equated to y, the roots can be obtained to any required degree of accuracy; or Horner's method may be used. Instead of plotting the whole curve, it is better to find out about where the roots are, and then plot those bits of the curve in a very open scale. On giving x the values 0, 1, 2, 3, 4, 5, we find that y has the values -25, 5, -5, -28, -17, 100; and since a change in the sign of y indicates that the curve crosses the axis of x, we see that the positive roots lie between 0 and 1, 1 and 2, 4 and 5 respectively. The first root is clearly inadmissible for our problem.

By using the angle θ we see that

$$b \operatorname{cosec} \theta + a \sec \theta = H;$$

and by plotting the curve $y = b \operatorname{cosec} \theta + a \sec \theta$, and finding where it is cut by the line $y = H$, we can obtain approximately the two values of θ.

Describe any alternating-current energy meter suitable for large powers (say 1000 amperes and 200 volts) with which you are acquainted, and explain how you would test the accuracy of such an instrument on an inductive circuit.—(*City and Guilds Examination, Honours*, 1904.)

Fig. 1 represents a Thomson recording wattmeter for heavy currents; as this is a well-known

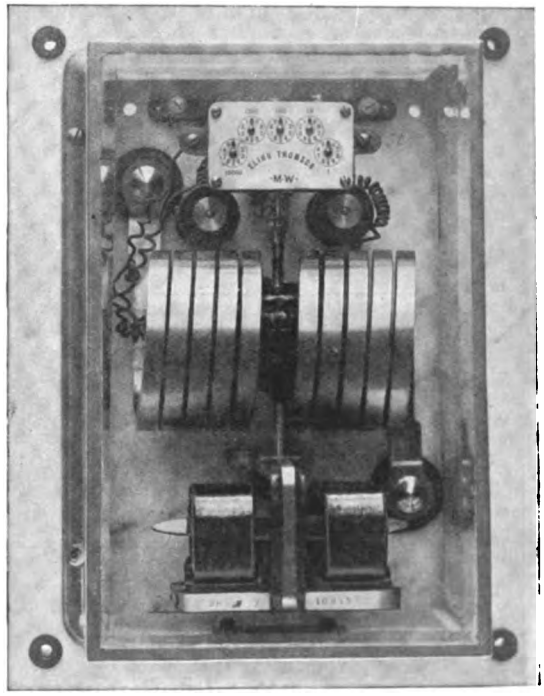
FIG. 1.—THE THOMSON RECORDING WATTMETER.

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type of instrument, the following brief description will suffice. It is an example of the motor type of meter, and consists of a peculiarly constructed electric motor, having no iron in either armature or field. The fields, which are composed of two coils of five turns of massive copper strip, coiled up one on either side of the armature, are connected in series with each other and with the circuit of which the absorption of energy is to be measured.

The armature is formed of a hollow frame wound with a set of coils of fine wire, on the

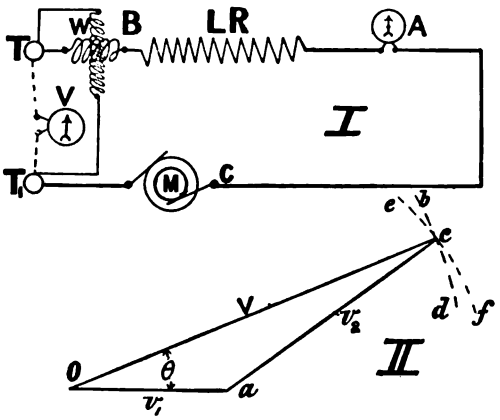

FIG. 2.—TESTING RECORDING WATTMETER.

Siemens drum principle; to them is attached a silver commutator, carried on the shaft near its upper bearing. Two light springs, with silver contact pieces, bear upon the commutator and constitute the brushes. The fine wire armature is in series with a non-inductive high resistance, carried in the frame at the back of the meter, and forms a shunt to the main circuit, the current in it varying from instant to instant with the voltage.

The torque at any given moment is proportional to the product of the current and pressure; and in order that the speed may vary as the watts, a retarding torque which increases in direct proportion to the speed is introduced by placing on the shaft a thin disc of copper, which rotates in a constant magnetic field between the poles of permanent magnets. These latter induce eddy currents in the disc, thus creating a drag on the motor. The shaft is geared with a train of wheels which forms the counting mechanism, so that the energy absorbed by the circuit is recorded.

The important part of the question refers to the method of testing the accuracy of such a meter when used on an inductive circuit. As is well known,

$$\text{true watts} = \text{volt-amperes} \times \text{power-factor}$$
$$= E \times C \times \cos\theta$$

where θ denotes the angle of lag between the current and the pressure. The conditions mentioned, *i.e.*, that the circuit is inductive, the impressed pressure 200 volt and the current large, suggests a power circuit; consequently we may assume that one or more induction motors are supplied with current, and also that in Fig. 2, I represents the circuit arranged for the test. T and T_1 are the terminals of the circuit, W the wattmeter to be tested, M induction motor, A a standard ammeter, V an electrostatic voltmeter reading up to 200 volts, and L R a fairly low resistance designed to carry 100 amperes, say. The pressures between B and C, C and T_1 may be obtained by means of the voltmeter. The current may be varied, it is assumed, by putting different loads upon the leads, and the readings of the ammeter: the readings of the voltmeter for the P. D's between T T_1, B C and C T_1 are observed, and the angle of lag, θ, may be found as follows. It must be noted that the resistance between the points B and C must be such that the drop in volts between them for the current used is not less than the lowest readings of the voltmeter. Let us suppose that the pressure between T and T_1, as given by the voltmeter, is V: the pressure between B and C is v_1; whilst v_2 is the pressure between C and T_1; then by drawing O a (Fig. 2, II) to scale to denote v_1; and from O an arc $b\ c\ d$ with radius equal to V (to scale), and from a the arc $e\ c\ f$ with radius equal to v_2, the vector diagram O $a\ c$ may be constructed, and the angle a O c gives θ the angle of lag. The indication of the wattmeter must of course be noted, and also the time, and the energy absorbed will be ($t \times V\ C \times \cos\theta$), where C is the current given by the ammeter and t is the time in hours. By repeating the above readings with different currents the accuracy of the instrument may be tested. It is, however, important to notice that everything depends upon the accuracy of the voltmeter readings, and extreme care is needed to make a satisfactory test.

TRIGONOMETRY.—A, B, C are three points in order in a straight line, and P and Q are two distant points to the North of AC. At A, and also at B, an angle of 45° is subtended by PQ; at C, Q exactly covers B. Show that—

$$PQ \cos 2\beta + (a + 2b) \sin\beta = \pm \cos\beta \sqrt{\{a + 2b^2 - 4b(a + b)\cos 2\beta\}}$$

where a, b, and β stand for AB, BC and ACP respectively.

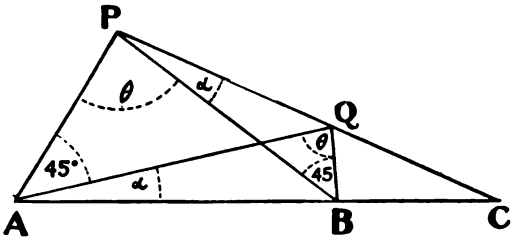

FIG. 1.—TRIGONOMETRY.

Since the angles PAQ and PBQ are equal (*viz.*, each 45°), the points ABQP are concyclic. Hence if the angles QAC, AQB, be denoted by α and θ we get at once from the figure that

$$45 + 2\alpha + \beta + \theta = 180.$$

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$$\text{Now } \frac{PQ}{\sin 45} = \frac{BQ}{\sin \alpha} = \frac{a}{\sin \theta}$$

$$\text{Hence } PQ \sin \theta = a \frac{1}{\sqrt{2}}$$

$$\text{Also } \frac{AQ}{\sin \beta} = \frac{a+b}{\sin (\alpha + \beta)}$$

$$\text{and } \frac{AQ}{\sin (\alpha + \theta)} = \frac{a}{\sin \theta};$$

$$\text{Hence } (a+b) \sin \beta . \sin \theta = a \sin (\alpha + \beta) \sin (\alpha + \theta)$$

$$= \frac{a}{2}(\cos \overline{\theta - \beta} - \cos \overline{2\alpha + \beta + \theta});$$

$$\therefore 2(a+b) \sin \beta \sin \theta = a \cos \theta \cos \beta + a \sin \theta \sin \beta + \frac{a}{\sqrt{2}}$$

$$\therefore \sin \theta . \sin \beta (a + 2b) - \frac{a}{\sqrt{2}} = a \cos \theta . \cos \beta.$$

Squaring and transposing, we obtain

$$\sin^2\theta \left\{(a+2b)^2 \sin^2\beta + a^2 \cos^2\beta\right\} - \frac{2a(a+2b)}{\sqrt{2}} \sin \beta \sin \theta + \frac{a^2}{2} - a^2 \cos^2\beta = 0.$$

Now $\frac{a^2}{2} - a^2 \cos^2\beta = -\frac{a^2}{2} \cos 2\beta$; and remembering that we want to find $PQ = \frac{a}{\sqrt{2} \sin \theta}$, we solve the quadratic for $\frac{1}{\sin \theta}$, the form being $\frac{1}{\sin^2\theta} X - \frac{2}{\sin \theta} Y + Z = 0$

$$\text{and } \therefore \frac{1}{\sin \theta} = \frac{Y \pm \sqrt{Y^2 - XZ}}{X}$$

$$= \frac{\frac{a}{\sqrt{2}}(a+2b) \sin \beta \pm \sqrt{\left\{\frac{a^2}{2}(a+2b)^2 \sin^2\beta + \text{etc.}\right\}}}{-\frac{a^2}{2} \cos 2\beta}$$

$$\therefore PQ \cos 2\beta = \frac{a \cos 2\beta}{\sqrt{2} \sin \theta} =$$

$$-(a+2b) \sin \beta \pm \cos \beta \sqrt{\left\{(a+2b)^2 - 4b(a+b) \cos 2\beta\right\}}$$

The required result.

DESIGN OF TANK. — Will you please indicate the simplest method of calculating the stresses on tie-rods and plates in a water tank of the form shown in section, and made of cast iron plates bolted together; also the loads on the supporting rolled steel joists. In this case, diagonal tie rods must be used to ensure clear space in tank.

It is usual to design the bottom plates as though they were wide thin beams supported by the rolled steel joists. No allowance is made for the thickened rims of the plates, as the bolt-holes detract so much from their strength. The section modulus of the bottom plates is thus taken at $\frac{1}{6} b d^2$ where b = the breadth of the plate, and d = the thickness in the panel or body of the plate.

As one cubic foot of water weighs 62·4 lbs., the pressure on the bottom plates in lbs. per square foot = 62·4 H where H = the total head or depth of the water in feet.

Let l = the length of a bottom plate in inches = the distance between the centres of joists.

The total pressure on one bottom plate

$$= 62{\cdot}4 \text{ H} \times \frac{l}{12} \times \frac{b}{12} = \frac{\text{H } l b}{2{\cdot}3} \text{ [lbs.]} = \text{W}.$$

The bending moment

$$= \frac{\text{W } l}{8} = \frac{1}{6} b d^2 f$$

where f = the safe stress on extreme fibres in pounds per square inch. For cast iron, f = 3,000.

Inserting the value of f, we have

$$\frac{\text{W } l}{8} = \frac{1}{6} b d^2 \times 3{,}000.$$

By expressing W in terms of H l and b, we have

$$\frac{\text{H } l b}{2{\cdot}3} \times \frac{l}{8} = 500 b d^2.$$

On dividing both sides of this equation by 500 b we obtain

$$d^2 = \frac{\text{H } l^2}{2{\cdot}3 \times 8 \times 500}$$

Let L = the length of the plate in feet, then

$$d^2 = \frac{\text{H } 12\text{L} \times 12\text{L}}{2{\cdot}3 \times 8 \times 500}$$

$$d^2 = \frac{\text{H L}^2}{63{\cdot}9}$$

$$\therefore d = \frac{\sqrt{\text{H}} \cdot \text{L}}{\sqrt{63{\cdot}9}}$$

or for all practical purposes

$$d = \frac{\sqrt{\text{H}} \cdot \text{L}}{8}$$

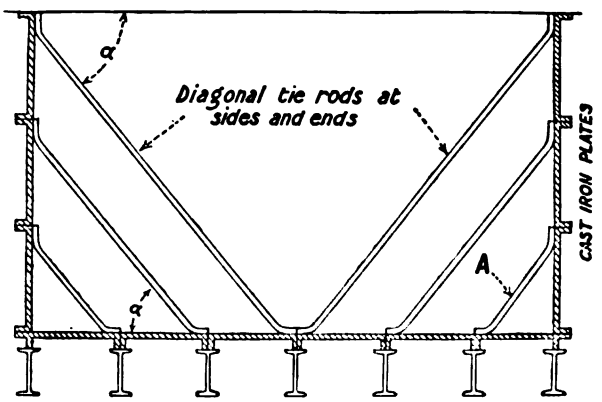

FIG. 1.—DESIGN OF TANK.

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Although the sides do not bear the same pressure per square foot of surface as the bottom plates, they are not held so securely; and may suffer greater stresses; therefore no reduction of plate thickness should be made except in large tanks efficiently framed and braced.

The purpose of the tie-rods is obviously to prevent the bulging of the tank sides. To find the requisite diameter we treat the tie-rod as though it were a boiler stay we had to deal with. First find the area of side-plates supported by each tie-rod. If the tie-rods are four feet apart vertically, and five feet apart horizontally, this area will be 20 square feet. Next find the mean pressure on this area. Then find the total pressure. This pressure will be the outward thrust which is to be resisted. If the tie-rods were horizontal, and ran through from one side of the tank to the other, the outward thrust would be the same as the total stress on the rod: but as the tie-rods are inclined at the angle *a* the total stress on the bar will be *Hor. thrust* × *s.c. a.*

In the case of stays at an angle of 45° the stress will be 1·4 × Hor. thrust.

As it is desirable to reduce the stresses in the tank sides by giving the plates as rigid a support as possible, it is not unusual to insert tie-bars of considerably greater area than would suffice to safely stand the tensile stress. The elongation of the stressed bar within is thus kept within safe limits.

The form of bracing shown is not very suitable for large tanks. It lacks rigidity. Some stiffening members should be inserted to take up the pressures from the plates with greater certainty.

LEATHER.—What quantities of vitriol, salt and water can be safely used to preserve fifty sheep-skin pelts, so that they may stand any warm climate; and how long would it be necessary to leave them in before being sufficiently preserved?

The constitution of a brining solution is:—vitriol 1 lb., salt 1 cwt., water 50 gallons, assuming that the pelts are fairly dry; but this would not preserve the pelts for a warm climate. For this purpose they should have a supplementary layer salting in addition. The amount of liquor required depends upon the capacity of the soaking tub or pit, but if fairly near the size of the pelts, the quantity given should do. The best process would be to fold the pelts down the back, flesh side in. Lay them in the brining pit, folded edge outward, so that they are "built up" in a stack; as each one is laid down, open it far enough to sprinkle about a pound of salt over the flesh. When the lot is done, pour in the brine. This will be sufficient to keep them about twelve months; all wet salted pelts come out bad in the tanning if kept longer than this. These pelts should be kept in the brine about two weeks, and then have the loose salt scraped from them. It would not be so effective if all the salt was added to the water with the vitriol, although it would save some time. If the skins are intended for making coloured leathers, white salt should be used; if for black, rock salt will do, but there is always some danger of iron stains where the latter is used.

TECHNICS CORRESPONDENCE.

SHRINKAGE AND WARPING OF TIMBER.

To the Editor of TECHNICS.

DEAR SIR,—In looking over the article on Timber published in the last issue of TECHNICS, I notice that the titles of Figs. 3 and 4 have by some mistake been exchanged.

I regret my omission to acknowledge that Figs. 3, 4, and 5, representing the micro-structure of boxwood, are due to Mr. A. H. Coote, F.C.S., of the Ordnance College, Woolwich, to whom my sincere apologies are tendered.

Yours faithfully,

H. BUSBRIDGE.

228, Burrage Road,
Plumstead, S.E.
July 15th, 1904.

RESISTANCE OF METALS AT LOW TEMPERATURES.

To the Editor of TECHNICS.

DEAR SIR,—In connection with the letter of Mr. S. Irwin Crookes on this subject in your issue of July, may I call your attention to a letter from Dr. E. Philip Harrison in "Nature" of 7th August, 1902, wherein he gives an experimental result on the resistance of iron at the temperature of liquid hydrogen. He found that the curve of resistance of iron had a turning point just below −200° C., the resistance of the specimen tested being greater at −253° C. than at −191° C. The quotation made by Mr. Crookes from Professor Dewar's address to the B.A. meeting is to be found in "Nature" of 11th September, 1902. Dr. Harrison's experimental result on iron seems to have been overlooked.

I am, Yours faithfully, R. MACDONALD.

The Irish Technical Journal,
Upper George St., Kingstown, co. Dublin.
July 18th, 1904.

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£25 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 80 competitions have been given in the preceding seven numbers of TECHNICS.

The present number contains particulars of 7 competitions, for which money prizes amounting, in the aggregate, to £25 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£25 IN PRIZES.

General Rules.

Competitors are requested to note the following rules: —

All writing must be on foolscap paper, only one side of which is to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat flat preferred. They must not be creased. They must also be executed in black ink.

N.B. —All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editor reserves the right to withhold the prize.

All competitions must be addressed to the Competition Department, TECHNICS, 12, Burleigh Street, Strand, W.C., and must reach these offices not later than September 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

THEORETICAL MECHANICS.

£3 for the best answer.

A boat is drifting down a smoothly-flowing river. Is it possible for the boat to travel at a greater rate than the water in which it floats? Explain your answer fully. (Neglect effects of wind and air friction.)

RADIUM.

£3 for the best answer.

It has been suggested that radium is a chemical compound of helium and some (possibly unknown) element. Discuss the evidence for and against this view; if it is correct, in what important respects does radium differ from other chemical compounds?

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PRACTICAL MECHANICS.

£3 for the best answer.

Describe the most efficient forms of friction clutch with which you are acquainted, and discuss their individual advantages and disadvantages. Give working drawings of the clutches you describe.

WEAVING.

£3 for the best answer.

Describe the Jacquard loom, with diagrams. Discuss the lines along which you think improvement in weaving is likely to take place.

ELECTRICAL ENGINEERING.

£3 for the best answer.

Discuss the relative advantages and disadvantages of (1) continuous current motors, and (2) alternating current motors, in connection with systems of electrical power distribution.

ELECTRIC WAVES.

£5 for the best set of answers.

1. Define the "inductance" of an electric circuit. Prove that the instantaneous back E.M.F. in a circuit of inductance L is equal $\left(- L \frac{d C}{d t} \right)$, where $d C$ is the increase in the value of the current which takes place in the small interval of time $d t$.

2. Prove, in the simplest possible manner, that if the inductance of a circuit is equal to L, and the current circulating in the circuit is equal to C, then the magnetic energy of the circuit is equal to $L C^2/2$.

3. Prove, in the simplest possible manner, that the energy E of a charged condenser is given by the following equations :—

$$E = \frac{Q V}{2} = \frac{K V^2}{2} = \frac{Q^2}{2 K}$$

where Q = electrostatic charge of condenser.
V = potential of charge.
K = capacity of condenser.

4. Is it correct to say that electricity is a form of energy? Give reasons for your answer.

THEORY OF STRUCTURAL DESIGN.

£5 for the best set of answers.

1. Give a brief synopsis, in a series of numbered paragraphs, of the arguments employed in bringing out the abstract character of radii of gyration of beams and columns, and give your own opinion on the desirability of a more descriptive nomenclature.

2. Find the least radius of equivalence (or of gyration) for the following sections, each of which is built up of one rolled steel joist, with equal top and bottom flanges.

(*a*) 24 ins. × $7\frac{1}{4}$ ins. rolled steel joist at 100 lbs. per ft., with 12 ins. × $\frac{5}{8}$ in. plates.
(*b*) 20 ins. × $7\frac{1}{8}$ ins. rolled steel joist at 90 lbs. per ft., with 12 ins. × $\frac{5}{8}$ in. plates.
(*c*) 18 ins. × $6\frac{1}{4}$ ins. rolled steel joist at 70 lbs. per ft., with 12 ins. × $\frac{5}{8}$ in. plates.

The minimum geometrical "moments of inertia" for the above sections may be taken as—
48·6 ins.^{4}, 49 ins.^{4}, and 24·6 ins.^{4} respectively.

3. What general ideas should govern the determination of sections for built-up mild steel stanchions?

4. In the study of structural theory, what point or points do you consider the most difficult to grasp and realise?

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PERSONAL ITEMS.

MR. A. BALFOUR will deliver the presidential address at the meeting of the British Association at Cambridge, on Wednesday, August 17. The address will be delivered at the Corn Exchange, at 8.30 p.m. At 3 p.m., on Thursday, August 18, the High Sheriff of Cambridgeshire will entertain the Association at a garden party in the grounds of Emmanuel College.

A MONUMENT to Pasteur was unveiled in the Place Breteuil, Paris, on July 16, by President Loubet.

A BILL has been introduced into the House to regulate wireless telegraphy. The bill makes no attempt to create a State monopoly in wireless telegraphy, but aims only at regulating its use so as to avoid undue clashing. The Government will, however, claim the right to control wireless telegraphy in time of war.

MR. DUDDELL has recently been experimenting in Bushey Park on the subject of wireless telegraphy. Mr. Duddell uses a thermo-galvanometer in his researches; the waves caught by the aerial wire create a current which passes through a wire, the heat produced in which acts on a thermo-junction, arranged as part of a suspended electrical circuit somewhat like that used in Boys's radio-micrometer. This method is the only one extant in which the energy of the electric waves is directly measured.

SCIENCE scholars at the Royal College of Science, London, selected from the whole of Great Britain for their ability and promise, are only allowed 17s. 9d. per week for their maintenance. This year Prof. Perry's kindly efforts have induced a number of private individuals to give small private bursaries. Prof. Perry says that he has no right to ask further help from the generous men who assisted him last year, but he has all the sturdiness of a chartered beggar. He asks in a good cause, and we wish to direct attention to Prof. Perry's efforts. During last year £248 was subscribed, and this, added to £31 held over from the preceding year, gave a total of £279. At present there is a balance in hand of £24.

AT a recent meeting of the London County Council, Sir William Collins stated that the Senate of the London University has accepted the gift of the Goldsmiths' Institute, New Cross. The London University proposes to open a day training college at the Institute, in the autumn of 1905. Day classes in preparation for the intermediate examinations in arts and sciences will be formed, together with evening classes in preparation for the final degree examinations. The London University will be unable to carry on the recreative side of the Institute, but it is announced that a great part of the evening science and technical classes will be maintained as heretof re, at any rate during the next year.

ON June 22, the degree of D.Sc. *honoris causa* was conferred by the Oxford University on the Hon. C. A. Parsons, Signor Guglielmo Marconi, Sir Andrew Noble, Sir William Crookes, Prof. J. J. Thomson, Sir James Dewar, and Prof. Larmor.

THE annual dinner of the Northampton Institute (Day Students) was held at Anderton's Hotel, Fleet Street, on Friday, July 8. There was a large gathering of both students and staff; amongst others, Dr. Walmsley, Dr. Drysdale, and Messrs. C. E. Larard, S. Field, and W. E. Curnock were present.

SIR WILLIAM CROOKES has found that diamonds exposed to radium emanation are changed in colour. He suggests that the treatment of diamonds by radium may possibly assume commercial importance; it may be possible to lighten "off colour" stones, and to communicate decided colours to "fancy" stones. A diamond, thirty-five days after it had been removed from the presence of radium, still retained its induced radio-activity, although during ten of these days the diamond was immersed in a solution of concentrated nitric acid and potassium chlorate at 50° C.—a solution which can dissolve even graphite.

IN a paper by Dr. Vaughan Cornish, in the *Geographical Journal*, it is shown that the height of deep sea waves, in feet, is approximately equal to one half the velocity of the wind in statute miles per hour.

A COMMITTEE appointed by the Board of Trade in January, to inquire and report on the statutory requirements relating to the gas supplied by the metropolitan gas companies, recommends that the calorific value of the gas should be determined and recorded.

THE Wolseley Tool and Motor Car Co. have forwarded us a card of standard limits for cylindrical pieces: a table of approximate amounts to be left for grinding: and three admirably got-up pamphlets, on a self-opening die head, a horizontal boring machine, and caliper gauges respectively. Any of these can be obtained on application to the Wolseley Tool and Motor Car Co., Adderley Park, Birmingham.

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RESULTS OF MAY COMPETITIONS.

MOTOR CARS.

PRIZE, £5.—E. Dobson, 20, Victoria Terrace, Clarendon Road, Leeds.

SPECIAL HONOURABLE MENTION :—A. P. Hubbard ; Philip Hopkins Smith : Jas. Rhodes, H. G. Lester ; Francis Leonard Bell ; Hubert E. Briscoe-Macdonald.

HONOURABLE MENTION :—R. I. Mussell-white ; J. Boswell Wilton ; S. Irwin Crookes ; Harold Slicer ; Albert Whittaker.

THEORY OF STRUCTURAL DESIGN.

PRIZE, £5.—Arthur Gadd, 5, Pine Grove, Victoria Park, Manchester.

SPECIAL HONOURABLE MENTION :—John Thomson ; Fred. Mayer ; H. Topham.

HONOURABLE MENTION :—B. H. Penn ; William Redpath ; Harold Slicer.

MOTOR STARTING RESISTANCES.

PRIZE, £5.—Charles Ernest Savage, 133, Station Street, Loughborough, Leicestershire.

SPECIAL HONOURABLE MENTION :—R. E. C. Ihlee ; John H. Cowell ; Percy P. Jones ; P. A. Spalding. (All these designs present features of exceptional merit. *A consolation prize of £1 has been awarded to each.*)

HONOURABLE MENTION :—R. M. Sheppard ; S. E. Allen ; M. G. Tweedie ; Leonard Miller ; T. E. Weaver ; Francis Leonard Bell ; A. Ghee.

DYNAMO COMMUTATION.

PRIZE, £2.—P. E. Banting, Mona House, Manor Road, Rugby.

SPECIAL HONOURABLE MENTION :—A. Ghee ; R. E. C. Ihlee.

BOOT AND SHOE MANUFACTURE.

PRIZE, £3.—F. L. Hornsby, Lower Union Street, Desborough, near Market Harborough.

SPECIAL HONOURABLE MENTION :—Walter Bedford ; F. J. W. Streeton.

HONOURABLE MENTION :—Henry J. Payne ; Harry Dickenson.

HOW TO SET THE ROLLERS IN COTTON MACHINERY.

PRIZE, £3.—J. E. Tytler, 26, Meller Road, Slade Lane, Longsight, Manchester.

SPECIAL HONOURABLE MENTION :—H. Eigenbertz.

HONOURABLE MENTION :—Richard Churnley ; Frederic Stones ; John Hague.

POTTERS' MATERIALS.

PRIZE, £3.—Divided equally between two competitors : A. D. Holdcroft, 19, Park Terrace, Tunstall, Stoke-on-Trent ; Frederick Ward, 32, Wilson Street, Stoke-on-Trent.

SPECIAL HONOURABLE MENTION :—Ernest Walls ; Percival Marson.

PAPER MANUFACTURE.

PRIZE, £3.—James M. Ross, c/o. Grosvenor, Chater & Co., Limited, 68, Cannon Street, E.C.

SPECIAL HONOURABLE MENTION :—Thomas Newlands.

HOMEWORK COMPETITIONS.

(*d*) **Chemistry.** PRIZE, £3.—H. Harding, 47, Streathbourne Road, Upper Tooting, S.W.

SPECIAL HONOURABLE MENTION :— S. I. Crookes.

HONOURABLE MENTION :—Geo. W. Agar, C. Cronshaw.

(*f*) **Cotton Spinning.** — PRIZE, £3. — A. Brierley, 9, Belgrave Street, Rochdale.

SPECIAL HONOURABLE MENTION :—Chas. E. L. Jones.

HONOURABLE MENTION :—Herbert Wroe.

(*g*) **Weaving.**—PRIZE, £3.—Chas. E. L. Jones, 111, Acomb Street, Moss Side, Manchester.

SPECIAL HONOURABLE MENTION :—H. P. Curtis. *A consolation prize of £1 has been awarded to Mr. Curtis.*

HONOURABLE MENTION :—Wm. Miller ; J. Norris.

(*h*) **Boot and Shoe Manufacture.**—PRIZE, £3. —Austin T. Tuck, 70, Aspinall Road, St. Catherine's Park, Brockley, S.E.

SPECIAL HONOURABLE MENTION :— Harry Dickenson ; William John Tasker ; Daniel Edwin Rootham ; T. Chown ; Henry J. Payne ; Sydney Gilby ; Charles Spencer ; F. J. W. Streeton.

No Homework Books in (*a*) **Metallurgy,** (*i*) **Building Construction and Carpentry,** and (*k*) **Naval Architecture** were submitted.

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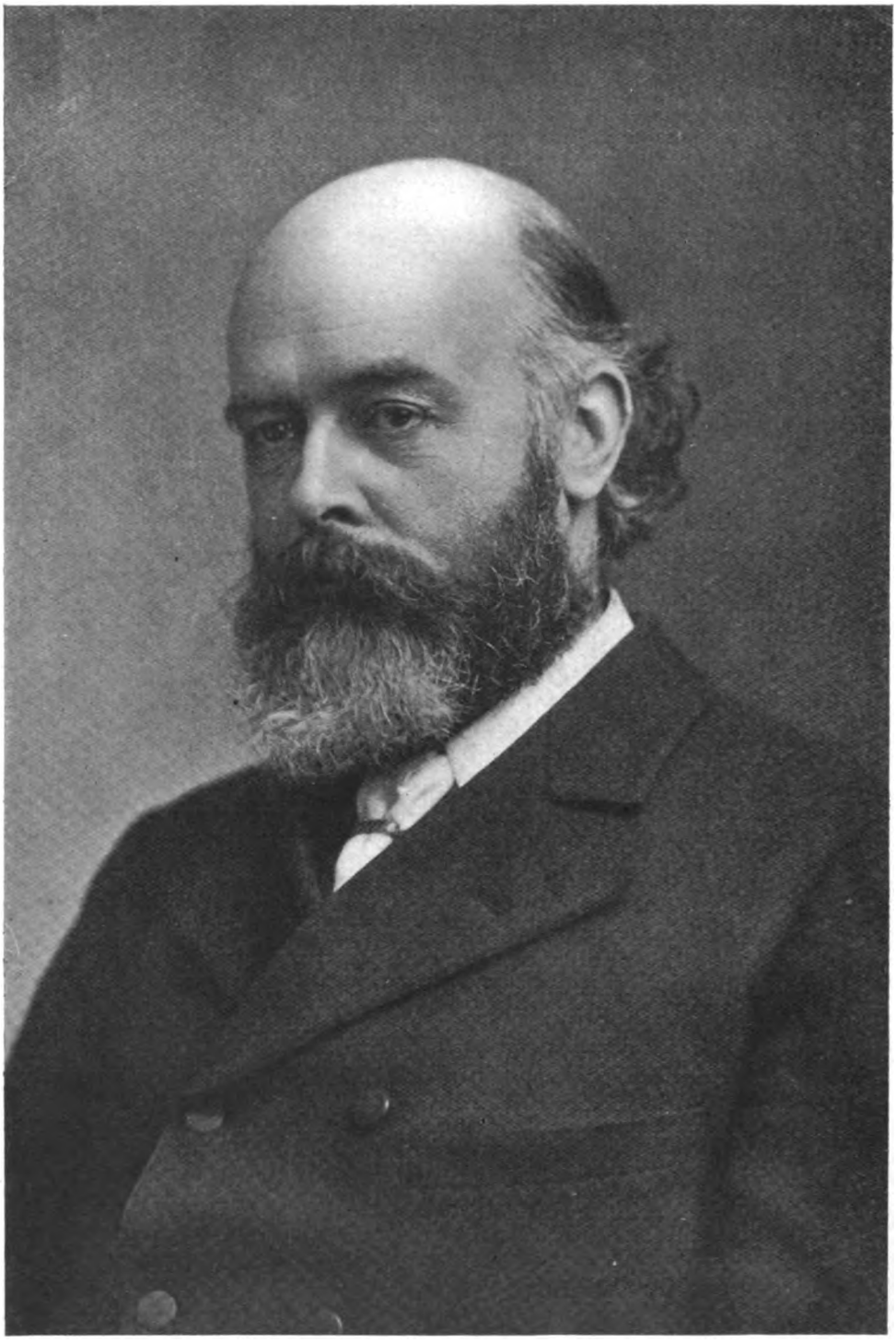

Sir OLIVER JOSEPH LODGE, M.Sc., F.R.S., D.Sc., LL.D., Principal of the University of Birmingham.

Photo. by Elliott and Fry.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. II. SEPTEMBER, 1904. No. 9.

PROGRESS OF SCIENCE AND TECHNOLOGY.

DURING the experimental preparation of cyanides in the electric furnace, in presence of free nitrogen, calcium cyanamide is found to be produced. By heating mixed lime or chalk and charcoal at 2,000°C. in a current of air, the same substance is formed. Under these conditions the nitrogen of the atmosphere enters into combination, and the chief product is calcium cyanamide. Experiments at Darmstadt and Posen have proved this substance to be a manurial agent of value. Similar experiments are in progress at Rothamsted.—(*Times*, July 18th, and Bulletin of the Imperial Institute.)

Production of Calcium Cyanamide by aid of Atmospheric Nitrogen, and its use as a Manure

In this connection it is interesting to recall Sir W. Crookes' Presidential address to the British Association at Bristol in 1898.

THE transmutation of metals, the dream of the alchemists, now appears about to become an established fact. Although till quite recently little evidence was forthcoming to indicate the possibility of this process, many eminent scientists, including Herbert Spencer, Sir William Crookes, Sir Norman Lockyer, and others, have from time to time expressed the opinion that the elements are merely complex forms of one universal substance; and if this be so, it follows that their transmutation presents no intrinsic impossibility. The work of Rutherford and Soddy shows that radium disintegrates into a number of simpler substances, one of which is helium; but there has heretofore been no experimental proof that the simpler elements can be built up into those which are more complex. In an article on the Periodic Arrangement of the Elements, contributed to the June number of TECHNICS, Sir William Ramsay discussed the possibility of converting an element into another of higher atomic weight, and quoted Ostwald's suggestion that this process would require the concentration of energy into the simpler element. The most concentrated form of energy is that given off by radium and its products during their disintegration; and the following experimental results obtained by Sir William Ramsay appear to indicate that he has effected the synthesis indicated above (*Nature*, August 11, 1904).

The Transmutation of the Elements

During experiments on the emanation of radium, about 105 milligrams of radium bromide, dissolved in water, were kept in small glass bulbs connected to a pump. To protect the bulbs from injury, each was surrounded by a small glass beaker, one beaker being of potash glass, and the other two of soda glass. The potash glass became coloured brown in the course of six months, while the soda glass became violet. A similar coloration had previously been noted by other observers, but the subject has attracted little attention.

Sir William Ramsay found that each beaker had acquired the property of radio-activity on both surfaces; and, what is most remarkable, *the radio-activity is removed by washing with water*. The water, after being used to wash the beakers, contains an emanation dissolved in it; for on bubbling air through it, the air acquires the property of discharging an electroscope, a property which is lost when the air is cooled by passing through a spiral immersed in liquid

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air. Now it is known that the emanation of radium is incapable of passing through even a thin layer of glass, so that the substance which gives the glass its radio-active property is not radium emanation. In confirmation of this conclusion, it was observed that the rate of decay of the emanation is much more rapid than that of radium, being more closely allied to the emanation of actinium. So far as we know, the only radiations which could have traversed the walls of the glass bulb are the β and γ rays; of these, the γ rays are akin to light rays, whilst the β rays consist of particles much smaller than the hydrogen atom. Nevertheless, one or other of these forms of radiation must have formed the emanation clinging to the walls of the beakers; it appears most probable either that the β particles combine to form complex aggregations, somewhat in the way described by Sir Oliver Lodge elsewhere in this issue; or that the radiations (either β or γ) affect the transmutation of the elements contained in the glass.

The most interesting result obtained by Sir William Ramsay, however, is that radio-active substances are dissolved in the washing water, which can be separated by ordinary chemical methods. For instance, on adding a soluble ferric salt to the solution, and precipitating in the form of ferric hydroxide, the radio-activity of the solution was lost; but precipitating a mercurous salt in the form of mercurous chloride failed to remove the activity of the solution.

It may be said that the above results are still far from sufficient to justify the theory of the transmutation of the elements; but it must be admitted that they constitute an important step in our study of the elements, and it is possible that, if they are followed up, as they are sure to be by Sir William Ramsay and others, they may finally lead to the realisation of the dream of the alchemists.

Radioactivity of Incandescent Metal Wires

In a paper recently read before the French Academy of Sciences, Tommasina records some recent experiments made by himself on monopolar electric dispersion, as produced by a metal wire heated to redness by the electric current, and placed either parallel to the vertical disc of an electroscope, or between the two plates of a condenser one terminal of which is connected to the ground, and the other to an electroscope.

The discharging effect, according to Tommasina, is not necessarily unilateral, as had hitherto been supposed. On the contrary, even at the lowest active temperatures, all metals are found to act on both electricities, though there is a considerable difference between the two effects. This difference depends on the sign of the charge: it increases with the time that the current is kept on in the case of metals producing a more rapid decay of negative charges, as, for instance, iron and copper; while, on the other hand, it decreases with metals for which the maximum activity has an opposite sign, as, for instance, silver and zinc.

A zinc-plated iron wire, after producing for some time a more rapid decay of positive charges, will gradually show smaller differences, until both effects become equal, when a difference in the opposite direction begins to manifest itself, the decay becoming finally the same as that of pure iron, when the whole zinc has disappeared.

The difference between the two decays, as characteristic of the various metals, gradually decreases for augmenting current intensities. In fact, on very strong incandescence or a partial melting of the wire, the two decays become practically equivalent, while the radioactivity assumes the maximum value. If the wire be cut through, the explosive discharge passing at the rupture will result in the same decay, no matter whether the electroscope be charged positively or negatively, and is independent of the nature of the metal wire. It is hence inferred that these results are not due to ultra-violet rays, which, as is well known, produce only the discharge of polished negatively electrified metals.

The radioactivity of any metal wires heated to redness by the electric current will decrease according to an asymptotical curve. However, it suffices to rub the wire slightly between the fingers, or even to leave it to itself for some time, to restore its maximum activity. In the case of platinum, the maximum decay of which is observed with negative charges, a similar fall of the radioactivity is observed, while only the positive decay seems to show a decrease with time.

If the radioactivity of the wire has become very small, the wire is found to remain radio-active for a long time on the current being broken. This phenomenon disappears nearly completely when the wire is rubbed, or spontaneously after an interval varying according to the nature of the wire and the duration and intensity of the current used. In the case of the wire being surrounded by a jacket of glass or aluminium (the latter being connected to earth), the cover will assume a radioactivity of its own.

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These phenomena must necessarily be due to a radioactivity induced in the incandescent wires. The author has made further investigations in this direction, in the course of which he has detected the presence and studied the action of the typical α, β, and γ radiations.

The α radiation is arrested by any, even the thinnest, screen; it seems to diffuse in the open air, with a very marked tendency to follow the electric flux; it always carries a positive charge.

The β radiation will traverse very thin paper and aluminium screens, which absorb a large portion of it, becoming negatively electrified.

The γ "Pyrorays" will produce a strong ionisation of the air, resulting always in the same discharge, independently of the charge of the electroscope. While capable of penetrating through a closed pasteboard box, they undergo a strong damping effect. On barium-platino-cyanide screens they induce a fluorescence, though of very low intensity. The rays are given off in greatest amounts from incandescent platinum wires, and from explosive discharges between any metal wires.

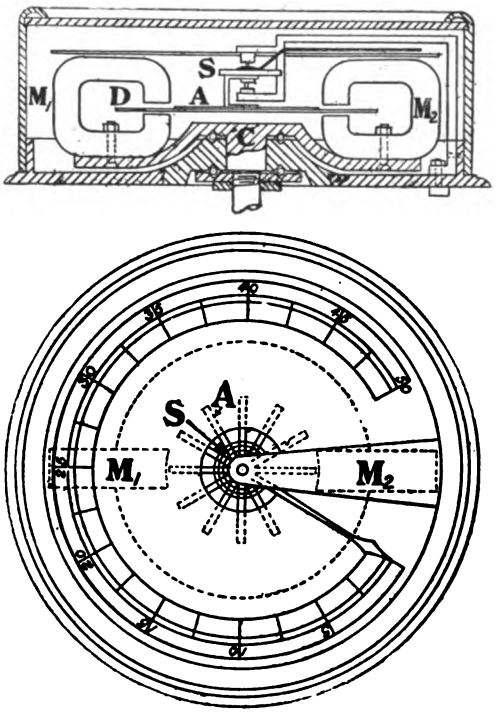

FIG. 1.—SECTIONAL ELEVATION AND PLAN OF MAGNETIC SPEED INDICATOR.

AT the Motor Car Show held a few months ago at the Agricultural Hall, Islington, a very ingenious speed indicator of novel design was exhibited.

A Magnetic Speed Indicator

Details of the construction were not then available, as the complete patent specification* had not been filed. This has now been done, and Fig. 1 gives a cross-section and plan showing the principle of the construction of the instrument. It is similar in principle to a Blondel-Carpentier hysteresis meter; that is, two or more permanent magnets, M_1 M_2, attached to a carrier C, are rotated around an iron armature A, which is lightly suspended on jewelled centres and controlled by a hair spring S. As the magnets rotate, they tend to draw the armature after them, the amount of deflection being controlled by the spring. This indicator differs from the Blondel-Carpentier instrument since the speed of rotation of the magnets is not constant, and the armature has always the same amount of iron in it, not being variable by the addition of different samples of iron.

When the carrier C is rotated at a speed proportional to that of the shaft of which the rate is to be measured, the deflection of the soft iron armature is found to be directly proportional to the speed, so an equally calibrated scale having a wide range can be used. Attached to the under side of the armature is a copper or aluminium disc D, which passes between the poles of the rotating magnets. The Foucault or eddy currents induced in this disc by the rotation of the magnets, damp the movement of the armature and prevent it from oscillating, thus making it dead-beat. The carrier C is supported on ball bearings, so that there may be as little friction as possible; but any friction which may occur here has no effect on the accuracy of the instrument, the only detrimental frictional resistance being that of the jewelled centres upon which the armature and damping disc are supported; and as these parts can be made very light, friction is reduced to a minimum, thus greatly increasing the sensitiveness of the instrument. In order that the magnets may act more effectually on the armature, it is made in the form of a twelve-armed spider. To reduce the depth of the instrument, it will be noted that the armature and damping disc are hung beneath the jewel bearings by means of a small bracket.

The inventors have provided for some other attachments in connection with this indicator, such as a speed limit alarm, in which case a

*Oades and Gratze Patent, No. 4748, June, 1904.

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movable pointer, connected to an ordinary electric bell circuit, is set at the point on the scale indicating the maximum speed desired. The hand of the instrument is so arranged that when this speed is reached it touches the limit pointer, the electric circuit is closed, and the alarm rung.

To indicate the maximum reading of the instrument, a loose pointer is suitably attached to the scale and pushed round and held by friction at the position of the highest deflection made by the indicating hand.

To give the sum of the total revolutions, an ordinary revolution counter is geared to the magnet carrier.

The instrument is certainly very simple in principle and construction: frictional errors are reduced to a minimum, and the scale readings are equidistant and have a wide range. The design of the instrument, from a mechanical point of view, appears to be a little crude at present, but this will probably soon be remedied. It shows evidence of a great deal of ingenuity having been expended upon it.

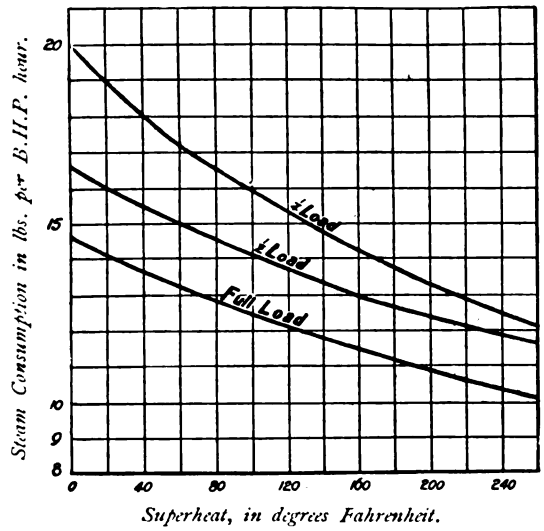

FIG. 2.—CURVES SHOWING RELATION BETWEEN SUPERHEAT AND STEAM CONSUMPTION FOR WILLANS ENGINE.

As pointed out on page 390 of the April number of TECHNICS, the pencil streak high resistance, although simple and eminently cheap, can hardly be regarded as anything but a failure, owing to its unstable nature. Much the same may be said of the smoke film resistance, which increases considerably with time, and with the ordinary tinfoil or electrolytically deposited copper terminal invariably gives trouble by breaking down at the joint. The cause of this latter failure is very simple. Tinfoil or deposited copper possess uniform thickness, and in each case there is consequently an abrupt step down on to the glass, that, although perhaps very minute, is sufficient in time to cause the smoke layer to subside at this point, increasing the resistance very greatly, or perhaps even completely breaking the circuit.

Smoke Film High Resistances

This difficulty has been effectively got over in the following manner The end of the glass plate is dipped into a salt of silver solution, and a coating thus deposited which, by capillary attraction, takes the form of a gentle slope, the deposit being thickest at the extreme end of the glass strip and fading down to practically nothing some little way up. The smoke film is deposited on the top of this, and the whole treated with some preservative compound such as shellac varnish. A resistance constructed upon these lines increases slightly with age, but with ordinary careful usage will not break down or give trouble in any way. Connection may be made by electrolytically depositing copper on the end of the silver until sufficient thickness is obtained to allow of a wire being soldered on.

AN interesting pamphlet, giving the results of experiments on the use of superheated steam in connection with the Willans engine, has recently been issued by Messrs. Willans and Robinson, Victoria Works, Rugby, from whom copies can be obtained on application. A number of Willans engines have been running for several years under superheat conditions, and the experimental results are now published, since the makers have satisfied themselves that high temperatures have no prejudicial effects upon the working parts of the engine. Good results have been obtained, using steam at a temperature of 600° to 700° F. It has been found that less oil is required than with saturated steam, and the price of oil of the necessary quality for use at high temperatures is moderate. The glands of the engine are packed either with phosphor-bronze or with cast-iron rings. The rings used in connection with the glands, piston, and valves are all of the spring type; consequently while always remaining tight, the clearance is sufficient at all temperatures. If solid valves were used,

Superheated Steam and the Willans Engine

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the clearance required at high temperatures would introduce leakage at low temperatures. The curves in Fig. 2 show the steam consumption per brake horse-power hour of a 210 B.H.P. Willans engine, at one quarter, half, and full load, for various degrees of superheat. The engine tested was of the triple expansion condensing type, running at 400 r.p.m.; the boiler pressure was 185 lbs. per square inch, and the vacuum 28 inches. The very small steam consumption of 10 lbs. per B.H.P. hour, obtained at full load and a superheat of 260° F., is probably the finest performance of a steam engine on record.

WHILE the efficiency of the incandescent mantle, as a light producer, is beyond dispute,

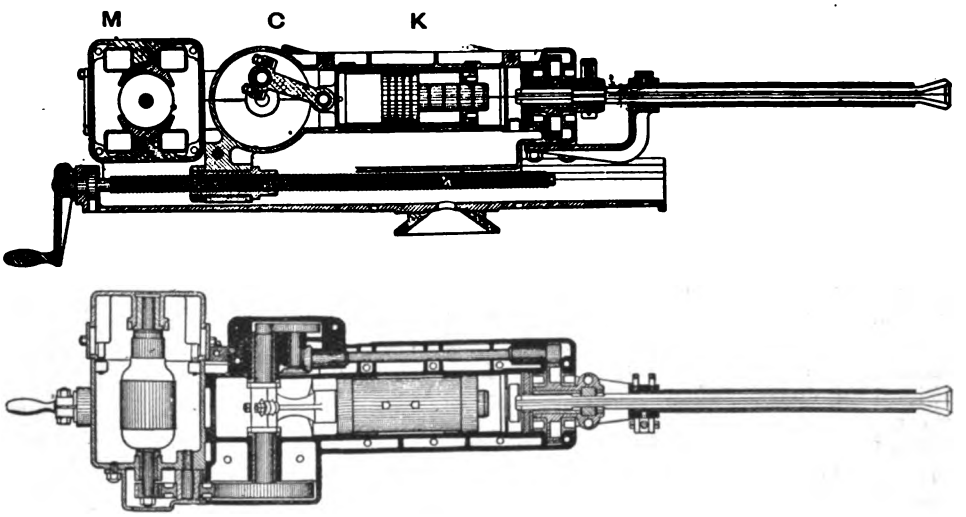

FIG. 3.—SECTIONAL ELEVATION AND PLAN OF ELECTRO-PNEUMATIC ROCK DRILL.

An Electro-Pneumatic Rock Drill

COMPRESSED air drills have been in use in metalliferous mines for many years, while electric drills are only now coming to the front. Compressed air drills are wasteful in power, each drill requiring from 12 to 15 h.p. at the compressor. On the other hand, the electric drill has heretofore failed to gain the confidence of mining men, since its action depends on the alternate compression and elongation of steel springs. The Denver Engineering Company has recently perfected an electrical drill (Fig. 3), in which air, compressed within the drill itself, takes the place of the springs. An electric motor, M, forms part of the drilling machine, and turns a crank C, which imparts a reciprocating motion to a cylinder K. Inside the cylinder is a free piston made especially heavy, as is likewise the piston rod attached to it. The forward motion of the cylinder compresses the air behind the piston, which tends to remain stationary in virtue of its inertia till set in motion by the pressure of the air behind it; finally the piston rod strikes the drill just as a hammer would. The drill is turned continuously in its chuck, just as if it were held in the hand of a miner. In addition, the drill is enclosed in a tube through which a stream of water passes under pressure; the water cleans out the drill hole, and prevents the dust from rising and entering the lungs of the miner.

Inverted Gas Mantles

the ordinary "petticoat" pattern is not altogether without drawbacks. The mantle must be made of a certain length in order to fit the gas flame; and since the mantle is hung freely from its upper extremity, and at its open end embraces the burner tube, vibrations tend to hasten its disintegration. The Inverted Incandescent Gas Burner has been designed to overcome these drawbacks. The Bunsen tube is inverted (Fig. 5), the lower part being made of porcelain, above which air is drawn in at adjustable apertures in a metal tube. The mantle is nearly hemispherical in shape; its open end is attached by asbestos cord to a porcelain ring provided with three projections which fit into small lugs on the burner tube (Fig. 4). This form of mantle, rendered possible by the shape of the inverted flame, is well designed to be unaffected by vibrations. The appearance of the lamp is very much like that of an electric

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lamp—its resemblance to the Nernst lamp is very striking. It is obvious that no shade will be cast downwards by any attachment to the lamp,—an important advantage where a desk or billiard table is to be illuminated. The burners are made in two sizes: No. 1 gives an illumination of 65 candle-power, and burns 3 cubic feet of gas per hour; with gas at 3*s*. per 1,000 c. ft., the cost for 1,000 hours amounts to 9*s*. The *Bijou* burner gives an illumination of 20 candle-power, and burns one cubic foot of gas per hour; with gas at the price mentioned above, the cost for 1,000 hours works out at 3*s*. The burners and mantles are supplied by the New Inverted Incandescent Gas Lamp Co., Ltd., 23, Farringdon Avenue, E.C.

FIG. 4. METHOD OF ATTACHING INVERTED MANTLE.

The Right to Light

THE erection of a new building in a town is becoming a task attended with great legal risk. Elsewhere in this issue Mr. J. Oddy explains the present state of the law with regard to the Right to Light; but it is evident that in the present state of affairs it is extremely difficult to say when a building can be safely erected in a town. When it is remembered that builders are restricted in divers directions by legal enactments, prescribing the method of procedure which must be followed in building operations, it appears to be only fair that some safeguard should be given that a building shall not be condemned after its completion. The London County Council has powers to prevent the erection of unsafe structures; why could not the Council, or some other body, be placed in a position to decide whether the erection of a building constitutes a nuisance to the occupiers of existing buildings in the neighbourhood? At present those who consider themselves injured by the erection of a building must wait till it has been erected before legal remedy can be sought; and the fact that the decision in the lower courts in the case of *The Home and Colonial Stores* v. *Colls* was reversed in the Court of Appeal, and re-reversed in the House of Lords, shows that there are no very definite grounds on which such complaints can be judged. In England, too, the law is an expensive remedy; there are few people like Mr. Colls who are willing, even if they are in a position, to fight a case out to the bitter end. Had Mr. Colls not carried the case to the House of Lords, the decision of the Court of Appeal, requiring the new building complained of by the Home and Colonial Stores to be pulled down, would have formed a precedent for future cases. Americans say that it is only a question of time before twenty-storey buildings will make their appearance in London; but in spite of the successful termination of Mr. Colls' final case, it would appear that great courage would be necessary to erect even a much smaller building in our capital, unless large sums of money had been spent in acquiring the consent of the owners and occupiers of already existing houses in the neighbourhood.

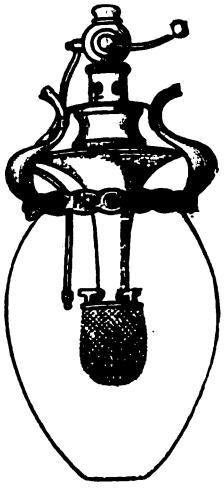

FIG. 5.—INVERTED BURNER AND MANTLE.

Synthesis of Rhodinol

BOUVEAULT and Gourmand, two French chemists, have prepared rhodinol from the synthetical ethyl ester of geranic acid, by the action of sodium and absolute alcohol. Rhodinol and a second alcohol resulted. Further, from synthetic geranic acid by reduction (using sodium and amyl alcohol), they prepared rhodinolic acid, converted it into its ethyl ester, and from the latter, again by the action of sodium and absolute alcohol, produced rhodinol—in this case the racemic variety. This isomer has the characteristic rose odour, and differs only in optical behaviour from natural rhodinol.

Nitrogen and Vitality

EXPERIMENTS conducted by Dr. Arturo Maracci, at Palermo, have shown that the affirmation by Regnault and Reiset in their treatise on respiration, that if the nitrogen of the atmosphere were replaced by hydrogen life would still be possible, is at fault. When surrounded by an atmosphere in which hydrogen replaced nitrogen, animals died. The symptoms implied that the deaths were due to cold: the high thermal conductivity of hydrogen would account for this. An increase of the oxygen absorbed and the carbon-dioxide evolved occurred.

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CHEMICAL AFFINITY.

By Sir OLIVER J. LODGE, M.Sc., F.R.S., D.Sc., LL.D., Principal of the University of Birmingham.

THE attraction of opposite electric charges, with a force inversely as the square of the distance between them, is a well-known and definite phenomenon; and though it is true that a good deal remains to be discovered concerning the nature and vehicle of the force, yet it may be taken as a fundamental starting-point for problems in physics and chemistry, just as gravitation can be taken as a starting-point for problems in astronomy, and cohesion for problems in engineering. The real nature of the force is known in none of these cases: perhaps rather more is known about the nature of electric force than about that of either of the others, and it has recently become a question whether cohesion cannot be explained in terms of residual or surplus electric attraction.

The three apparently distinct and quite certain kinds of force are electric, magnetic, and gravitational. For large masses of matter such as are dealt with in astronomy, gravitation overpowers every other kind of force, and on a large scale may be said to dominate the material universe. But when dealing with small particles, or moderate masses of matter, chemical and electric and cohesive forces are much more energetic than gravitation. When a mass so large as the earth is concerned, it would be hard if the tenacity of a wire could not support a weight; and even with regard to the vastly greater mass of the sun, the pressure of its light and its electrical repulsion quite overpower its gravitative attraction on extremely small bodies in its neighbourhood, such as apparently constitute the tail of a comet; and their apparent weight is therefore negative, so that they fly from it with prodigious rapidity, some of them producing auroral and magnetic disturbances as they fly with their electric charges into or past the atmosphere of the earth.

What has all this to do with chemistry? The force of chemical affinity, which binds atoms together in a molecule, has long been suspected to be purely electric; and just as electric attraction between bodies may be called chemical action at a distance, so the chemical affinity of one atom for another is simply electrical attraction at close quarters. Every atom of matter is liable to possess an electric charge—the so-called atomic charge—and in this condition it is an active ion. The great bulk of atoms are doubtless neutral; but some of them under certain conditions acquire either a positive or negative charge, and it is to these that chemical activity is due. It is the possession of these charges which also makes matter amenable to electric influence, to electro-chemical decomposition, and the like. Some atoms possess only a single unit of charge: others possess a couple of units, which may or may not be of the same sign: others again possess three, some four, and so on as high as six; it appears to be doubtful whether any atom possesses more than this number of units of charge in the unneutralised or active condition.

It may be said, How can an atom possess two opposite charges without their neutralising each other? The answer is very easy: the charges may be located at opposite ends of a diameter, just as the earth has a north and a south magnetic pole. So also four or six charges, whether of the same or of opposite sign, can be easily supposed dotted about in regular grouping on or near the surface of an atom. For an atom is not an infinitesimal thing: it is small, but it has a definite size; and by its surface is meant the boundary of its immediate sphere of activity—the range into which no other atom can be squeezed without extraordinary violence—the range within which cohesion acts in full vigour. Within this sphere of activity the atom resides, with all its parts, and with any free charges which may belong to it. It appears to be a complete micro-cosmos in itself, full of movement and energy and activity, not at all the small

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hard lump which some perhaps once supposed it to be.

This being so, how are we to conceive of the aggregation of atoms into compound molecules? If a positively charged atom and an equal negatively charged atom approach one another, they may obviously be expected to combine. Suppose they do; have they, thereby, neutralised each other's activity, and lost all attracting force for other charges in their neighbourhood? Or does the satisfaction of their main attraction leave still a residual affinity which can exert an effect on other atoms which happen to approach too near? The answer is quite simple and can be given either by theory or by experiment. It is perfectly certain that residual affinity must exist: that a given charge is by no means completely satiated by a single opposite equal charge, but that it may take on at least three, possibly four, equal charges before it declines to receive any addition.

Experiments can most easily be made on models of atoms, free to move only in one plane; and thus it is found that not more than three of one sign can group themselves round another of opposite sign, and that if a fourth is brought up, one of the three immediately goes away. But to this system, with one positive surrounded by three negatives, another *positive* may cling with ease; and after that some more negative can also be taken on, and so gradually a great number of regular and complex patterns can be built, even out of floating models, each with one attracting centre only. The easiest way to try the experiment is to utilise the attracting force of magnetic poles, which obey the same inverse-square law of distance as electric charges. By enclosing a number of long, thin magnets in vertical floats like hydrometers, it is possible to arrange so that their similar or opposite poles shall come near each other, the upper ones acting on each other near the surface of water, and the lower ones also acting on each other at a different depth; the upper and lower strata being fairly independent of each other by reason of distance and inefficient angle. Fig. o shows one of these floating magnetic bulbs. In order to avoid capillary disturbance and to secure free motion, it is desirable that the part above the water shall be small, and that any protruding bulbous portion, which is to come into contact with similar things, shall be entirely submerged.

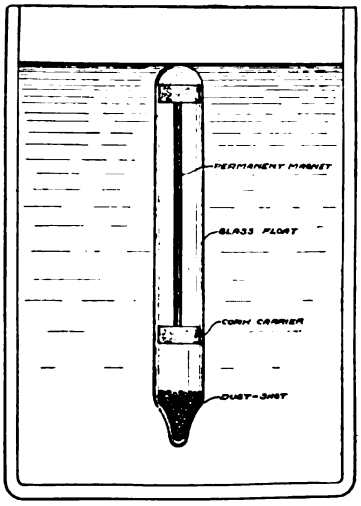

FIG. o.—MONAD FLOAT.

This being arranged, it is easy to study the groupings and make drawings of them—and this is done in the diagrams which follow—for a moderate number of such floats.

Copies of the drawings are appended, with notes expressive of the results of observations made on the instability of the various configurations; that is to say, their liability to break up or to change into other forms when subjected to irregular disturbances, such as may be produced by agitating the water in which they are floating. Positive and negative charges are distinguished by differences of shading.

It will be observed that the figures are numbered in accordance with the number of floats which go to form each pattern, and that after each number is a letter to distinguish between the different patterns each number of floats can give. The lettering is approximately and roughly in the order of stability; but to give a rather better estimate, a "mark" is awarded, in small Roman characters, representing the average of independent estimates of the stability of each group; x. meaning the most stable grouping possible, and i. or ii. meaning that the group can just be formed with a little care, but that the least disturbance breaks it up.

Notes accompanying the diagrams give further details. They are all based on simple experimental observation.

It is a striking fact how many varieties of grouping can be obtained from the number 8; and, of course, as soon as the number 12 is reached the variety of patterns will be vastly greater.

Prime numbers are not likely to give anything like so many configurations as numbers possessing numerous factors.

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FIG. 1.—Monad.

FIG. 2 (X.)—Quite stable.

FIG. 3 (X.)—Stable, though with violent agitation it may break up into 2 and 1.

FIG. 4A (X.)—Stable, not at all easy to break up. If violently agitated, very liable to break into four single floaters, which in general combine first of all as 3 and 1. Sometimes, but more rarely, as two of Fig. 2, the whole combining later on to form 4A again.

FIG. 4B (VII.)— A fairly stable combination sometimes formed when Fig. 4A is broken up ; it lasts some time, and then forms up into Fig. 4A. It is generally formed by the combination of two of Fig. 2, and if agitated tends to produce two of Fig. 2.

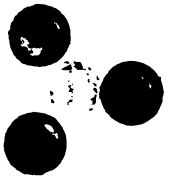

FIG. 4C (VIII.)—Stable, but with violent agitation breaks up in general into 2, 1, 1 ; sometimes into 3, 1 ; or 3, 1 is formed after breaking up from 2, 1, 1, by combination of 2 and 1, leaving 1 free. If a fourth of the same sign as the three, is brought up to Fig. 4C, one of the three already there at once sails away.

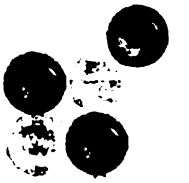

FIG. 5A (VIII.)—A stable combination ; when the water is violently agitated it tends to break up into Fig. 2 and Fig. 3. These in turn in general combine to form Fig. 5B, though almost equally liable to form Fig. 5A.

FIG. 5B (VIII.) is a stable combination. On agitating the water it is hard to say what forms it is most likely to break up into, but Fig. 2, Fig. 1, Fig. 2 appears most likely ; then comes Fig. 2, Fig. 3.

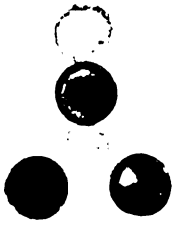

FIG. 5C (III.) is very unstable ; it swings round to form Fig. 5A.

FIG. 6A (VIII.) is a stable combination. On agitating the water it can form Fig. 4A and Fig. 2, or sometimes two of Fig. 3. It may also open out into a circle, Fig. 6C, and close up at right angles, forming 6A again.

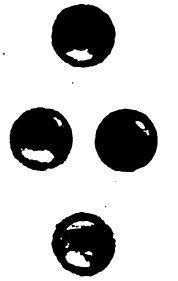

FIG. 6B (VI.)—Stable. On agitating the water it tends to break up into two groups of 3.

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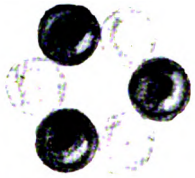

FIG. 6C (V.)—Fairly stable. On agitating the water it tends to change first of all into 6E, which changes into 6A. It may also break up into Fig. 4A and Fig. 2, these again combining to form Fig. 6A. It is also liable to break up into two sets of Fig. 3, or open out into a line 6D.

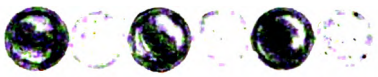

FIG. 6D (VI.)—Fairly stable. Tends to form Fig. 6A.

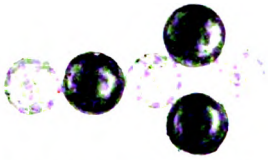

FIG. 6E (III.)—Not very stable. Tends to form Fig. 6A.

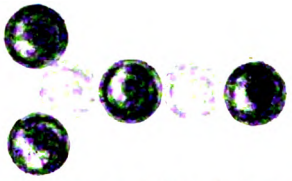

FIG. 6F (III.) is very unstable; it tends to form Fig. 6B.

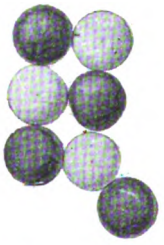

FIG. 7A (VII.)—Stable. Breaks up on agitating water into 3, 2, 2; also tends to open out into a line, 7B, which returns to Fig. 7A.

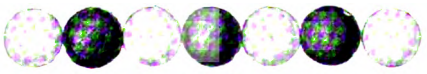

FIG. 7B (VI.)—Stable. The line may change into 7C, and from 7C into 7A.

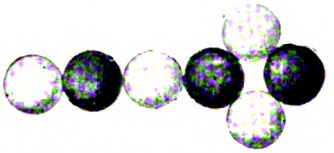

FIG. 7C (VI.)—Stable. Tends to break up into Fig. 4A and Fig. 3.

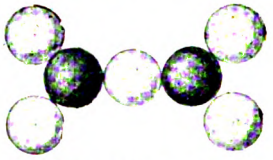

FIG. 7D (V.)—Very weak combination, tending to break up into Fig. 4C and Fig. 3 on very moderate agitation of the water. It illustrates the breaking up better than any pattern yet dealt with.

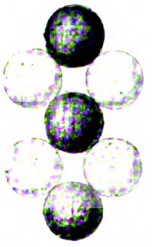

FIG. 7E (VI.)—Moderately stable. Tends to change into 7C.

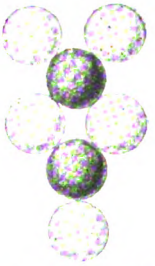

FIG. 7F (IV.) is a weak combination, changing into 7D.

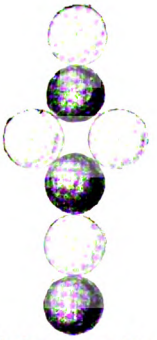

FIG. 7G (VI.)—Moderately stable, tending to form Fig. 7A.

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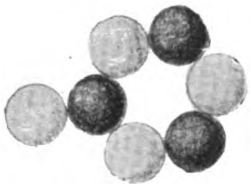

FIG. 7H (IV.)—Rather unstable, tending to form Fig. 7A.

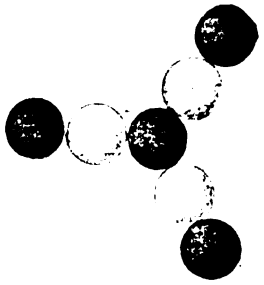

FIG. 7K (IV.)—Very unstable, tending to form Fig. 7A.

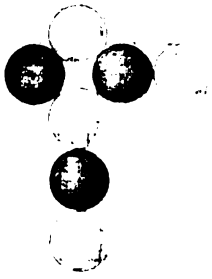

FIG. 7L (III.)—Very unstable indeed ; tends to form Fig. 7A.

FIG. 8A (IX.)—Quite stable. Cannot say that it has any particular way of breaking up on agitating the water.

FIG. 8B (IX.)—Stable. No particular way of breaking up. Tends to go all to pieces with violent agitation.

FIG. 8C (IX.)—Stable. On agitation has an inclination to form Figs. 2 and 6A.

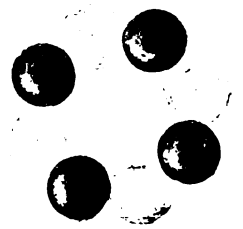

FIG. 8D (VI.)—Moderately stable ; tends to form Fig. 8B.

FIG. 8E (V.)—Rather unstable ; tends to form either Fig. 8D or Fig. 8B.

FIG. 8F (V.)—Moderately stable.

FIG. 8G (V.)—Not very stable ; tends to form Fig. 8B, or more weakly, Fig. 8K.

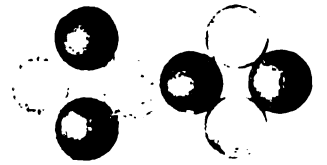

FIG. 8H (IV.)—Unstable ; tends to form Fig. 8B.

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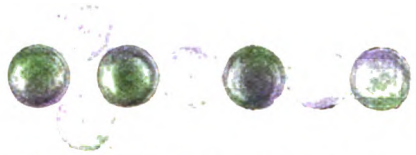

FIG. 8J (V.)—Fairly stable; tends to form Fig. 8B.

FIG. 8K (V.)—Fairly stable; on agitation of water passes into Fig. 8E.

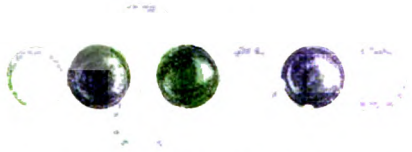

FIG. 8L (VI.)—Moderately stable. When it does fall together forms Fig. 8A.

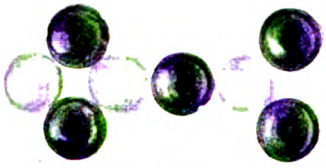

FIG. 8M (VI.)—Stable. On agitating the water breaks up into 4A and 4C, which recombine to again form Fig. 8M. Sometimes splits up into 5A and 3, which will combine again to form Fig. 8M.

FIG. 8N (IV.)—Unstable; tends to form into Fig. 8C.

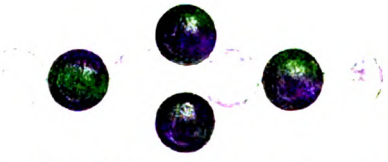

FIG. 8O (IV.)—Rather more stable than Fig. 8N; tends to form Fig. 8B.

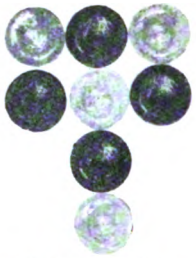

FIG. 8P (IV.)—Rather unstable; tends to form Fig. 8K.

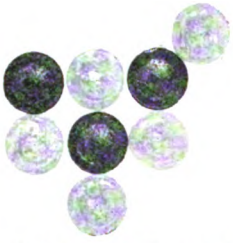

FIG. 8Q (IV.)—Rather unstable; tends to form Fig. 8A.

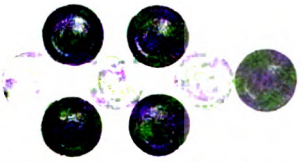

FIG. 8R (IV.)—Rather unstable; tends to form Fig. 8A.

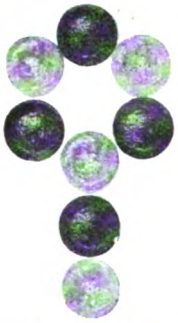

FIG. 8S (IV.)—Rather unstable; tends to form Fig. 8E.

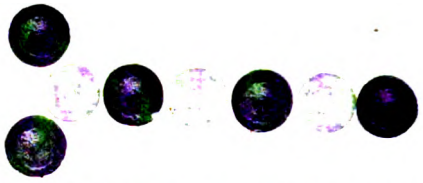

FIG. 8T (III.)—Moderately stable; tends to form Fig. 8L.

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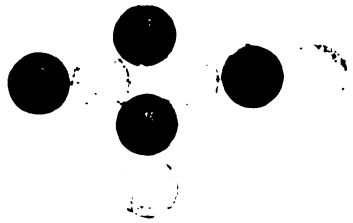

FIG. 8U (III.)—Very unstable; tends to form Fig. 8B.

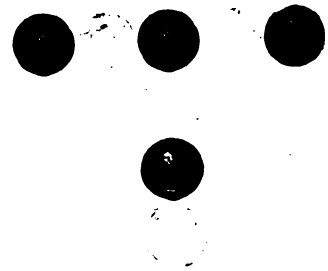

FIG. 8V (II.)—Very unstable; tends to form Fig. 8B.

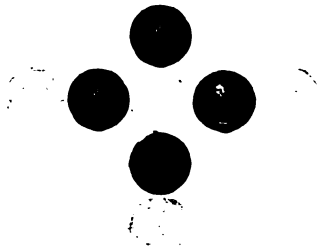

FIG. 8W (II.)

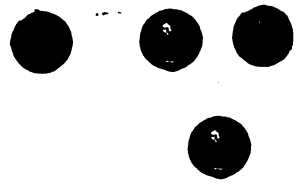

FIG. 8X (II.)

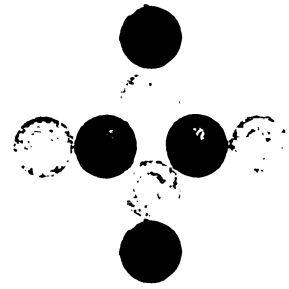

FIG. 8Y (I.)

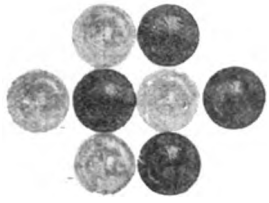

FIG. 8Z (II.)

Figs. 8W to 8Z represent patterns that are very unstable; care is necessary to form them.

So much for a system of attracting monads; but we can also make floats each of which contains two vertical magnets, or three, or four; thereby imitating diads, triads, and tetrads. We may make all similar poles correspond, or we may make them alternately positive and negative; thereby getting a variety. It is quite clear that a chemical tetrad, such as carbon or silicon, is not a strongly electro-negative or electro-positive element; accordingly it is quite unlikely that all its four attracting poles or centres of force are of the same sign: it is quite likely that they are alternately of opposite sign. The earth, in fact, might be regarded as a tetrad if its two magnetic axes were much more widely separated than they are. It may be said that such a combination of poles would, after all, only give the resultant effect of two, in some intermediate position, and so, for distant effects, they would; but on particles which approach within close range their action is different—on them the attracting centres have a definite holding influence. When such tetrads come into contact with each other they can cling into elaborate groupings, such as are familiar in organic chemistry, and can at the same time have any amount of residual affinity for other outlying atoms: some of these affinities being fairly strong, and the resulting compounds stable, others being weak and the compounds easily decomposed; while some also are easily liable to fall over into allotropic modifications.

Meanwhile the study of residual affinity seems best conducted by observing the groupings caused by single attracting centres, inasmuch as these represent cohesive forces governed by the law of inverse square; and there are certain radiation phenomena which seem to indicate that molecules do, as a matter of fact, cling to each other in accordance with this law. Accordingly, what we observe in the groupings of the floating magnets may be akin to the molecular aggregates which are to be expected when the molecules of definite chemical compounds find themselves closely packed together, as

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in a liquid or solid—especially in the liquid state, which is well known to be far the most efficient for the purposes of chemical union.

Once more I must repeat that the configurations here depicted are due to single attracting centres. The experiments on diads, triads, and tetrads, though begun, are not yet nearly complete.

Every molecule must be thought of as throwing out lines of attraction or residual affinity into space, which fasten upon and draw together other groupings, sometimes building them up into more complex aggregates, sometimes disturbing their equilibrium and putting them into other shapes, sometimes itself getting pulled to pieces by the surrounding diverse attraction of numerous stable molecules; so that a single grouping in the midst of many others of a different kind may have its lines of affinity so diverted and distributed that its own family connections get broken up; in other words, it finds itself unable to exist alone in the crowd, and becomes ionised; a strong chemical affinity thus being reduced to impotence by the individually weak attractions of a great number of others, thus explaining the influence of mass on chemical action.

Moreover molecules with their internal attractions thus weakened by the agency of a crowd of foreign molecules, may, if they happen to meet, combine with each other more readily and powerfully than would have been possible under ordinary conditions; and indeed it appears that a new light can be thrown on many of the long-known facts of chemistry by this doctrine of residual chemical affinity, which for some time has been instinctively felt and preached by many chemists as a necessity, and can now be realised as having a clear and definite physical or electrical basis, and as opening a new chapter which requires to be worked out.

Oliver Lodge

IMPURITIES IN STEAM.

THE "sand blast" action of certain kinds of steam, although demonstrated beyond doubt, is not so generally appreciated as the importance of its bearing upon the life of cylinder walls and other engine surfaces should warrant. When boilers prime, as many do when working at their full capacity, some of the deposited impurities, such as calcium carbonate, are carried over with the water, and, although part will doubtless remain in the piping, particularly at bends and valve pockets, a quantity that, no matter how small, must be injurious, is carried into the engine, cutting up the valve seatings and cylinder walls, and producing friction and heat generally. The use of superheated steam does not in any way reduce this action; experience with superheaters shows that they do not fur up, and as we know that lime deposits do actually leave the boiler under certain conditions of water and steaming, it is obvious that they must enter the engine with the dry steam in the form of dust. Some waters are very apt to scum, and such are the worst with respect to priming; it is, therefore, very necessary in such cases to fit scum cocks to the boilers and to use them as often as there is any appearance of this action having taken place. The obvious remedy is the installation of an efficient water-softening device that will eradicate all impurities before the water is fed into the boiler. Apparatus that will deal effectively with ordinary water is easily to be found, but extreme cases crop up now and again that present very great difficulties.

A proof that grit and dirt is actually carried out of a boiler by the steam may be found by examining the inside of a pipe range that has been in use for some time: as a rule a small deposit, similar in every respect to the familiar boiler scale, will be found.

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THE MECHANICS OF THE GYROSCOPE.

By EDWIN EDSER, A.R.C.Sc.

IN an article under the above title* Dr. Preston has described a simple yet effective way of explaining the characteristic mechanical properties of the gyroscope. The reasoning employed by Dr. Preston was purely qualitative in character, but it can be advantageously extended so as to obtain quantitative results. As, however, this extension presents one step of some difficulty, the following quantitative discussion of the problem may prove acceptable to those interested in the simple solution of mechanical problems directly from first principles.

According to the Newtonian system of mechanics, a force is required, not only to change the *numerical value* of the momentum of a particle, but also to change the *direction of the momentum*. When a stone falls to the ground, the force of gravity continually changes the magnitude of the stone's momentum; on the other hand, when a body revolves with a numerically constant velocity in a circular orbit, a central force is necessary, in order to continually change the direction of the momentum of the body.

Let D (Fig. 1) be a particle of a fly-wheel, rotating in the direction indicated by the arrow, about an axle perpendicular to the plane of the paper at C. If the direction of the axle remains unchanged, the particle at D will describe the circular path D A B. As already remarked, a central force will be required in order to constrain the element to follow this circular path; but as the method of evaluating this force (the so-called *centrifugal force*) is well known, nothing more need be said about it here.

Now let us suppose the fly-wheel to turn about the diameter A B, in a right-handed or clockwise sense when viewed in the direction from A to B. If the fly-wheel were not rotating about its axle, each particle would describe a circular path about the line A B, and a central force would be necessary, as before explained. When the fly-wheel is rotating about its axle, it is apparent that each particle must still be acted upon by a central force; but as this force is supplied by stresses in the fly-wheel, it need not be further considered.

Let ω be the angular velocity of the fly-wheel about the diameter A B. From D draw D F perpendicular to A B. When the particle is at D, its velocity perpendicular to the plane of the fly-wheel is equal to $\omega \times$ D F. After a short interval of time t let the particle reach the point E; at this instant the velocity of the particle perpendicular to the plane of the fly-wheel is equal to $\omega \times$ E G, where E G is the perpendicular distance of the particle from the axis A B. Draw E H perpendicular to D F; then the change in the velocity perpendicular to the plane of the fly-wheel, as

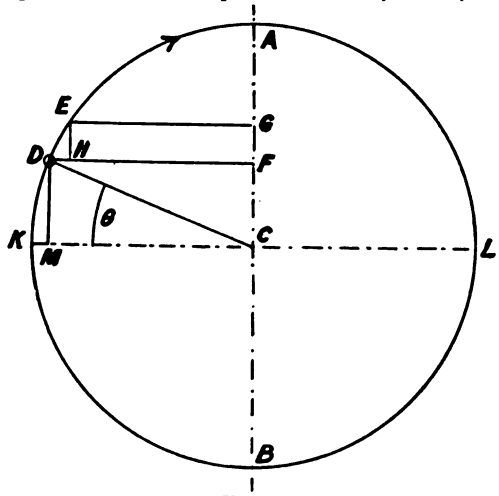

FIG. 1.

the particle moves from D to E, is equal to ω (D F − E G) = $\omega \times$ D H; and if m is the mass of the particle, the force necessary to produce this change of velocity is equal to $m\omega \times$ D H/t. Since the velocity of the particle is decreasing, the force on the particle must act upwards through the plane of the paper. The corresponding reaction will tend to turn the fly-wheel and axle about the diameter K L perpendicular to A B, in a right-handed sense when viewed in the direction from L to K.

In order to evaluate the force $m\omega \times$ D H/t, we may proceed as follows. Draw the radius

* "The Mechanics of the Gyroscope." By Dr. S. Tolver Preston. TECHNICS, Vol. II., No. 7, July, 1904, pp. 47-53.

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D C, and let $\angle D C K = \theta$. Since D E is a very small arc, it may be considered to be a straight line: then it is easily proved that $\angle D E H = \theta$. If D C $= r$, and the angular velocity of the fly-wheel about its axle is equal to ω_1, then the linear velocity of the particle is equal to $\omega_1 r$, and D E $= \omega_1 r t$. Then, since D H = D E sin D E H = D E sin $\theta = \omega_1 r t \sin \theta$, it follows that

$$\frac{m \omega \times D H}{t} = \frac{m \omega \times \omega_1 r t \sin \theta}{t}$$

$$= m \omega \omega_1 \cdot r \sin \theta$$

$$= \omega \omega_1 m \cdot D M$$

where D M is the perpendicular distance from D to the line K L.

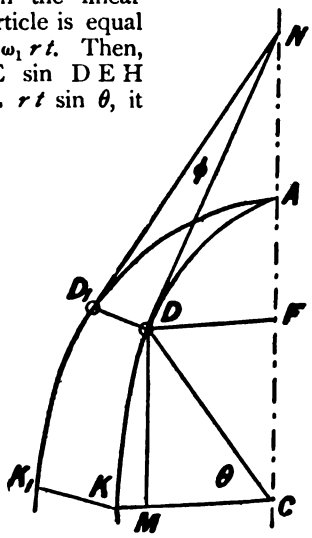

FIG. 2.

There is yet another force acting on the particle, which must now be considered. Owing to the rotation of the fly-wheel about the axis A B, the inclination of the plane of the fly-wheel is continually changing; and therefore the direction of motion of a particle of the fly-wheel is continually changing, irrespective of its motion around the circle D A B. In Fig. 2, K A C represents the perspective view of the quadrant K A C in Fig. 1, at the instant when the particle was at D. After the short interval of time t, the quadrant will occupy the position K_1 A C. The point D will have moved through the small arc D D_1 to the position D_1. Draw tangents to the two circles at D and D_1 respectively; then these tangents will cut the line C A produced to some point N. We have already determined the force called into play by the motion of the particle around the axle; we may therefore suppose that the particle, while retaining a numerically constant momentum equal to $m \omega_1 r$, is transferred from D to D_1 in the time t, the velocity always remaining in the plane of the fly-wheel. In the first positions of the particle, its linear velocity due to the rotation of the fly-wheel about its axle was equal to $\omega_1 r$, in the direction D N. In the second position of the particle, its linear velocity has the same magnitude, but it has acquired the direction D_1 N. We must now determine the force required to produce this change in the direction of the particle's velocity.

Let $\angle D_1 N D = \phi$. The initial velocity of the particle may be represented by D O $= \omega_1 r$ (Fig. 3), while its final velocity is equal to $D_1 O_1 = \omega_1 r$. From D draw D P equal and parallel to $D_1 O_1$, and join O P. Then the vector D P is equal to the sum of the vectors D O and O P, so that O P represents the velocity which must be added to D O in order to convert it into D P. Consequently, since this change of velocity occurs in a time t, the force necessary to produce it is equal to m O P$/t$.

Further, since the angle O D P $= \phi$ is small, the straight line O P will be approximately equal to a circular arc drawn through O and P with D as centre. Consequently, O P $= D O \times \phi = \omega_1 r \phi$.

To find ϕ, notice that the short line $D_1 D$ (Fig. 2) may be considered to be a circular arc with N as centre. Then $\phi = D_1 D / D N$.

The true value of $D_1 D$ is equal $\omega \times D F \times t$, where D F (Fig. 2) is the perpendicular distance of the point D from the line C A. Also D F $= C D \cos \theta = r \cos \theta$. Therefore $D_1 D = r \omega t \cos \theta$.

Further, $\angle N D C = \pi/2$, and $\angle N C D = \{(\pi/2) - \theta\}$; then D N $= C D \tan N C D = r \cot \theta$.

$$\phi = \frac{D_1 D}{D N} = \frac{r \omega t \cos \theta}{r \cot \theta}$$

$$= \omega t \sin \theta.$$

Finally, the force necessary to produce the change in the direction of the momentum of the particle,

$$= \frac{m O P}{t} = \frac{m \omega_1 r \phi}{t}$$

$$= \frac{m r \omega \omega_1 t \sin \theta}{t}$$

$$= \omega \omega_1 . m r \sin \theta$$

$$= \omega \omega_1 . m . D M \text{ (Fig. 1).}$$

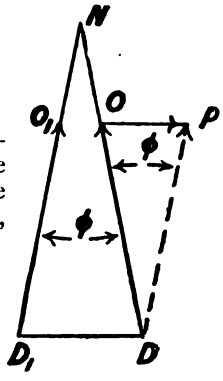

FIG. 3.

Thus the force necessary to change the mere direction of the velocity of the particle is equal to the force required to change the magnitude of the velocity perpendicular to the plane of the fly-wheel. Consequently the total force required to change the momentum of the particle at D (Fig. 1) is equal to

$$2 \omega \omega_1 . m . D M.$$

The moment of this force about the diameter K L (Fig. 1) is equal to

$$2 \omega \omega_1 . m (D M)^2.$$

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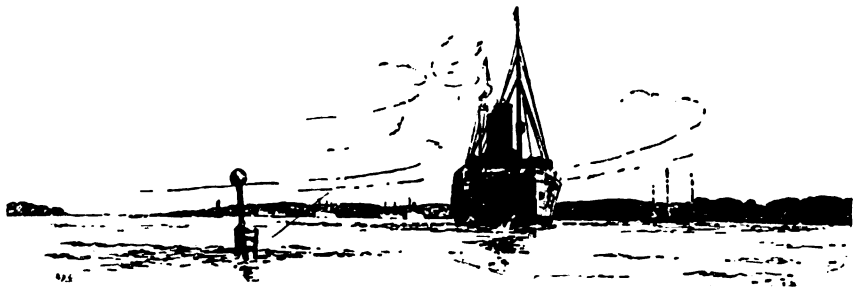
From this result it will be seen that the torque necessary to change the momentum of any particle is the product of two factors: one (*viz.*, $2\,\omega\,\omega_1$) is common to all particles of the fly-wheel; the other is equal to the mass of the particle multiplied by the square of its distance from the line K L. Consequently the torque required to change the momentum of the fly-wheel as a whole will be equal to $2\,\omega\,\omega_1$, multiplied by the sum of the terms obtained by multiplying the mass of each particle of the fly-wheel by the square of its distance from the line K L. This sum is the moment of inertia of the fly-wheel about the diameter K L—call this I. Then the total torque is equal to

$$2\,I\,\omega\,\omega_1.$$

In the above reasoning it has been tacitly assumed that the fly-wheel possesses the form of a thin disc, all particles lying in a single plane. Under these conditions, 2 I, or twice the moment of inertia of the disc about a diameter, is equal to the moment of inertia of the disc about the axis of rotation. If the fly-wheel possesses sensible thickness, we can divide it into a number of thin discs, and the torque required for a particular disc is equal to $\omega\omega_1$ multiplied by the moment of inertia of the disc about the axis of rotation. Consequently, the torque required for the fly-wheel as a whole is equal to $\omega\omega_1$ multiplied by the sum of the moments of inertia, about the axis of rotation, of the various constituent discs; and this sum is equal to the moment of inertia of the fly-wheel as a whole about the axis of rotation.

In the above I have endeavoured merely to obtain the torque necessary to constrain a fly-wheel to turn uniformly about a diameter, using the simplest and most direct reasoning; the properties of this torque were discussed by Dr. Preston in the article already referred to. In carrying out this investigation, I have not only had the advantage of previously reading Dr. Preston's article, but I have also received several instructive letters from Dr. Preston, dealing with the qualitative aspect of the question. Dr. Preston also informs me that, since writing his article, he has come across a similar investigation in Klein and Sommerfeld's treatise *Ueber die Theorie des Kreisels*, but developed by the aid of the higher mathematics. Klein and Sommerfeld ascribe the method to Corioli, who published a paper on the subject in section 24 of the *Journal de l'Ecole Polytechnique*, in 1835.

The value of the torque obtained above may be derived much more expeditiously by representing the moment of momentum at the beginning of the interval of time, t, by a vector drawn perpendicular to the plane of the fly-wheel, the moment of momentum at the end of the time t being represented in a similar manner. The line joining the free extremities of these vectors represents the change in the moment of momentum in the time t, from which the torque can easily be derived. This method, however, like other intellectual short cuts, fails to give us a clear insight into the fundamental principles involved.



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RIGHT TO LIGHT.

By JOSIAH ODDY, of the Middle Temple, Barrister-at-Law.

Proposition I.—The *Prescription Act*, 1832, has not altered the previous law with respect to ancient lights.

Proposition II.—The owner or occupier of a dominant tenement is entitled to the uninterrupted access, through his ancient windows, of such an amount of light as is required for the ordinary purposes of inhabitancy or business, according to the ordinary notions of mankind, without regard to the particular purpose for which the light is used.

Proposition III.—An obstruction which will justify the interference of the court must be of a character such as will constitute a nuisance.

Proposition IV.—The "rule of forty-five degrees" is not a rule of law, but might properly be used as *primâ facie* evidence.

INTO the above propositions may be crystallised the decision of the House of Lords in May of this year, in a case entitled *Colls* v. *The Home and Colonial Stores*.

The case passed through three phases.

In 1900, before Mr. Justice Joyce, Mr. Colls was successful in defending himself against the alleged nuisance of which The Home and Colonial Stores complained.

Later the Court of Appeal decided in favour of The Home and Colonial Stores.

Finally the House of Lords gave judgment for Mr. Colls, and at the same time settled the law regarding the "extraordinary amount of light" to which any person enjoying ancient lights is entitled.

The decision was a most important one, and was much commented upon at the time in legal publications and the more sober daily newspapers. Prior to this decision, the surveyor and builder had imagined that a rough measure of 45° of sky allowed for in their plans was all that could be required. The order made by the Court of Appeal for Mr. Colls to pull down his building and restore to The Home and Colonial Stores the *full* access of light it had always enjoyed, threatened to plunge the building world into confusion.

A careful examination of the law as it was before the decision of the House of Lords does not reveal such a serious departure from the current of judicial opinion as might be supposed. The conditions of modern life have probably far more to do with the apparent violence of the judgment than the actual decision of the judges themselves. It is because of the terribly congested areas existing in all great centres of population that this decision appears so difficult to conform to.

The Period of Twenty Years.

In the argument before the House of Lords, only one House of Lords case was cited. In this case, which dates back to 1865, Lord Westbury, Lord Cranworth, and Lord Chelmsford all assumed that a period of twenty years' enjoyment of the access and use of light creates an absolute and indefeasible right immediately on the expiration of the period of twenty years. But until the claim is questioned, no absolute and indefeasible right can exist under the Act. All the Act does is to give the owner of a dominant tenement, after twenty years' uninterrupted enjoyment, the opportunity to avail himself of the Act if his claim is questioned. But however long the enjoyment, the dominant owner's right is just the same, and the origin of this right is just the same as if the Act had never been passed. No title is as yet acquired under the Act.

The Act neither enlarges the right of a dominant tenement, nor adds to the burden of the servient tenement. What it does is this: When the access and use of the light has been enjoyed for the full period which, before the Act, was supposed to be sufficient to support a prescriptive claim, and the right is then brought into question, it avoids and extinguishes every adverse plea not founded upon an agreement or consent in writing.

The Right to an Extraordinary Amount of Light.

The crux of Proposition II. in our headnote may be said to have been first formulated thus—"the right to an extraordinary amount of light." That formula is awkward, and has led to conflicting decisions.

It may be taken that no man has a right to an extraordinary amount of light. He is only entitled to the light required for *ordinary* purposes of inhabitancy or business, according to the *ordinary* notions of mankind, and no

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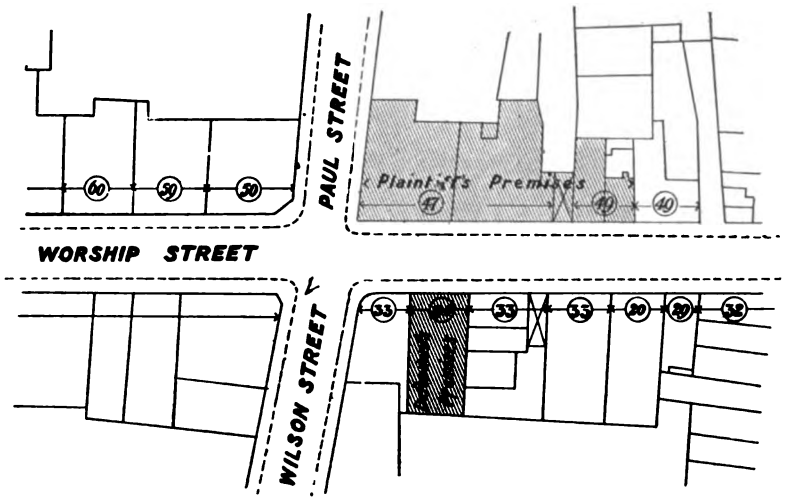

FIG. 1.—Diagram showing general plan of Worship Street, and height of plaintiff's and defendants' buildings and adjoining buildings, and access of light from cross streets—Paul Street and Wilson Street.

more. The particular purpose for which a man uses the light will not be taken into account. Yet for many years the law as to this appears to have been in the melting-pot. Judges have persistently tried to adapt the law to particular businesses or trades.

In 1897 Mr. Justice Kekewich, in a photographic case (*Lazarus* v. *The Artistic Photographic Company*), said: "It is beside the case to say that the plaintiff cannot claim light for the extraordinary purpose of photography because he has not photographed on these premises for the entire period of twenty years."

In 1900 Mr. Justice Wright declined to follow his learned brother in a case (*Warren* v. *Brown*) where, for the manufacture of hosiery by means of machinery, an exceptional quantity and quality of light was needed for the continual and accurate adjustment of filaments to fine needles moving at speed in bundles of some hundreds. A boot and shoe manufacture had been previously carried on in the same premises, requiring good but not extraordinary light. The Court of Appeal dissented entirely from Mr. Justice Wright, just as they dissented from Mr. Justice Joyce in the special case we are discussing. And so the law would have been left in its state of uncertainty but for the efforts of Mr. Howard Colls, who appealed to the House of Lords.

That House took the very practical view that no building could be erected if the decision in favour of The Home and Colonial Stores were correct.

A street forty-one feet wide separated the two buildings. The Stores' ground floor room ran fifty feet back from the street, and was lighted by windows in front only. The back part of the room had always required electric light except on very bright days. Mr. Colls pulled down an old building thirty feet wide and nineteen feet six inches high, and put up a building thirty-six feet wide and forty-two feet high from the level of the

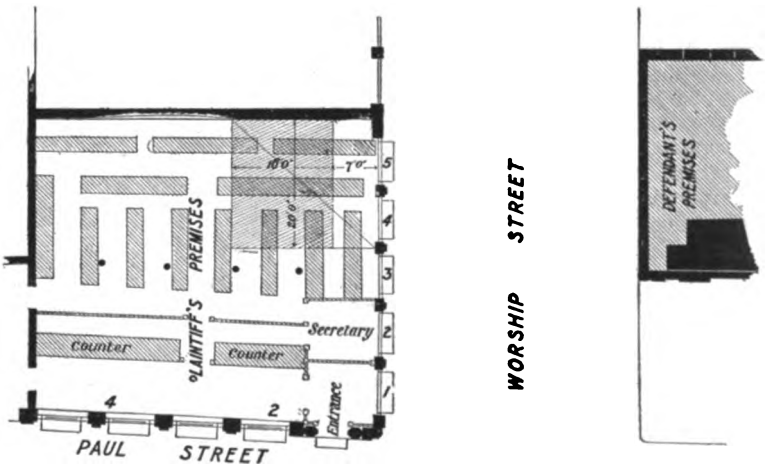

FIG. 2.—Diagram showing 5 windows lighting ground floor of plaintiff's premises, running back from Worship Street 50 feet. Window 5 was affected most by defendants' premises; 13 clerks sitting in area shown by shaded rectangle, complained that the distance from window at which sky might be seen was reduced from 23 feet to 7 feet—16 feet being left in the shadow. Back portion of room was always lighted artificially, except on very bright days. Worship Street is 41 feet wide.

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street. The buildings on each side of the one in question were thirty-three feet high, or thirteen feet six inches higher than the old building.

The ground floor of the Home and Colonial Stores' premises was twelve feet high and lit by five windows in a row, ten feet high and six feet wide, and the sill of each was three feet from the street level.

Reference to the diagrams will better indicate the position and the amount of sky obstructed.

What Amount of Obstruction is a Nuisance?

Proposition III. in our heading is vital to a proper appreciation of the law as it now stands. We have seen that to assume a right to an extraordinary amount of light led to false views and conflicting decisions. The negative claim embodied in Proposition III. gives the true principle for the solution of our difficulties.

The obstruction must cause such a diminution of light, such a "privation of light," as will constitute a nuisance. Such expressions as "a cone of light," "a specific quantity of light," are very misleading, and, coming from weighty authorities like Lord Justice Cotton and Lord Bowen, have led to the extreme view that the right acquired is a right to the continuance of the whole quantity of light which has come to any windows during a period of twenty years.

The stream of judicial opinion on the subject of obstruction was very clear until recent years.

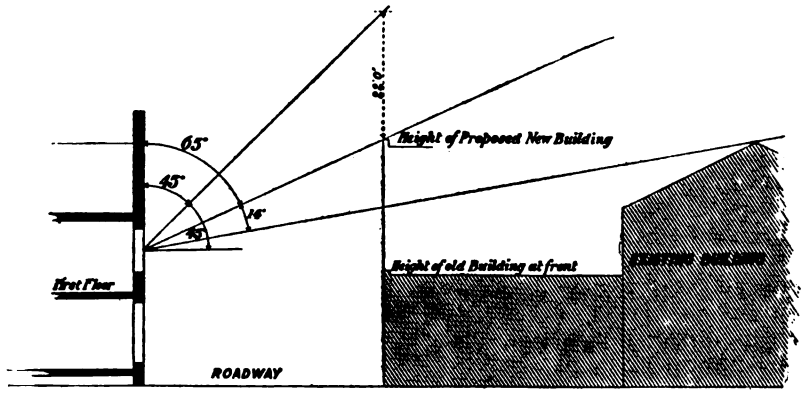

Fig. 3.—Diagram showing interference of light to first floor windows: angles measured from centre of window. Complaint dismissed at first hearing, there being no substantial interference, as building still allowed 65 degrees of light to first floor windows.

Lord Hardwicke, in 1752 (*Fishmongers Company* v. *The East India Company*), said: "If it clearly appeared that what the defendants are doing is a nuisance, I would put it in a way to be tried. But it is not a nuisance contrary to law; for it is not sufficient to say it will alter the plaintiff's lights, for then no vacant piece of ground could be built on in the city; and there will be seventeen feet distance, and the law says it must be so near as to be a nuisance. It is true the value of the plaintiff's house may be reduced by rendering the prospect less pleasant; but that is no reason to hinder a man from building on his own ground."

To the same effect is Lord Cranworth's judgment in 1865. "The plaintiff's rooms were rendered less cheerful, but I cannot think that this is such an obstruction of light as to amount to a nuisance. What the plaintiff was bound to show was, that the buildings of the defendant caused such an obstruction of light as to interfere with the ordinary occupations of life."

Lord Davy, in a few pithy words in his judgment, says: "The right to light has a ragged edge to it, and it is impossible to assert that any man has a right to a fixed amount of light ascertainable by metes and bounds."

In similar vein the Lord Chancellor says: "Light, like air, is the common right of all to enjoy, but it is the exclusive property of none. If there were a proprietary right in respect to air itself, the progressive building of any town would be impossible. The access of air is undoubtedly interfered with by the buildings which are being built every day round London. The difference between the town and country is very appreciable to a dweller in cities when he goes to the open country, or to the top of a mountain, or even a small hill in the country; but would the possessor for twenty years of a house on the edge of a town be at liberty to restrain his neighbours from building near him, because he had enjoyed the free access of air without buildings near him for twenty years?"

Lord Lindley put the matter in a rather different way from his learned brethren. It is a point of view to keep in mind, because it is opposed to the practice frequently obtaining among surveyors. He said: "The

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question is not how much light is left, but whether the plaintiff has been deprived of so much as to constitute an actionable nuisance. If he has, it is no defence to say that he has as much light left as most other people." This last sentence is a qualification of some words of Mr. Justice Wright in 1900 (*Warren* v. *Brown*). This learned judge seemed to think that there was a presumption that so long as 45 degrees or some approximate angle were left, there was no actionable wrong. And this brings us to our last proposition.

The Angle of 45 Degrees.

"The rule of 45 degrees is not a rule of law, and is not applicable to every case, but might properly be used as *primâ facie* evidence," said Lord Davy in his judgment in the case before us, adopting Lord Selborne's opinion in 1878 (*City of London Brewery Company* v. *Tennant*). Apparently surveyors, in advising those who consult them, and for the purpose of settling differences, have adopted this angle of 45 degrees as a working rule. Nor do they appear to be far wrong in ordinary cases. The danger has been in assuming that 45 degrees was an arbitrary standard to which every case must conform. It would seem that the presumption arose owing to an interpretation put upon Section 85 of the Metropolis Local Management Act Amendment Act of 1862 defining the height of buildings in certain streets. Mr. Justice North, following precedent, so decided in an action by a photographer in Holborn against the First Avenue Hotel Company in November, 1882. When the case came before the Court of Appeal in 1883, Lord Justice Cotton cleared up the matter once for all in these words: "It cannot possibly be that, as a matter of law, or as a matter of necessary inference, buildings at an angle of 45 degrees will not cause any interference with lights. The Lord Chancellor said in one case that where there was a large open street, and the buildings complained of on the other side of that street do not form a worse angle (than 45 degrees), that looked very much as if there would be no interference. But the interference only arises in such a case as that. Each case must depend on the fact whether the defendant's buildings do interfere with the plaintiff's lights. As I pointed out in another case (*Ecclesiastical Commissioners for England* v. *Kino*, 1880), the idea seems to have arisen from a reference to the Building Act, which was not intended to deal with questions of light, but to determine what was a reasonable width of street, having regard to the height of the houses on both sides, and as regards air and everything else. But if it is considered that there is any law or any inference of fact that this angle (45 degrees) is sufficient, the sooner the idea is got rid of the better. It must be a question of fact in each case."

In the case we are considering, it was argued for the Home and Colonial Stores that 23 degrees of light were cut off, and the distance from the window at which the sky might be seen was diminished from twenty-two

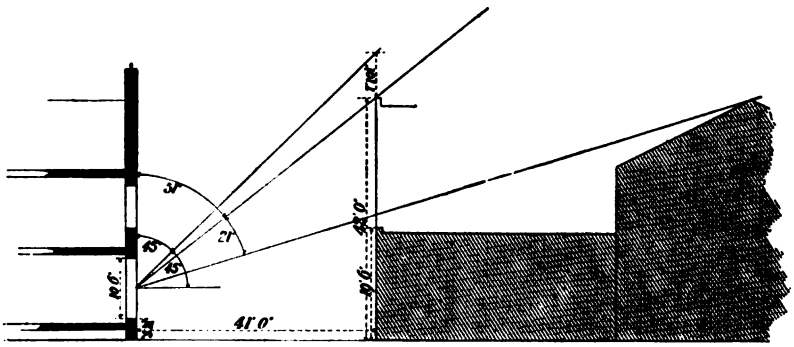

FIG. 3.—Diagram showing angle of light measured from centre of ground floor windows. It would allow 45 degrees of light if building had been raised 7 feet 10½ inches higher than it was actually built. (Compare with Fig. 2.)

feet to seven feet. These figures seem to show considerable diminution. But then the structure was peculiar. The room was fifty feet long and lighted only at one end; it was not built in the ordinary way, like a room in a dwelling-house, and was, for some purposes, too dark without the use of artificial light, even before the building on the other side of the street was erected; the building erected was not to be of the same height as the house belonging to the complaining neighbour. It would seem, therefore, that every case must depend on the particular facts of that case.

Chief Justice Best told a jury who had viewed the premises in 1826 (*Back* v. *Stacey*) that they were to judge rather from their own ocular observation than from the testimony of any witnesses, however respectable, of the degree of diminution which the plaintiff's ancient light had undergone.

This is approved to-day. Lord Lindley

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said that despite the elements of uncertainty which render it impossible to lay down any definite rule applicable to all cases, the good sense of judges and juries may be relied upon for adequately protecting the rights to light on the one hand and freedom from unnecessary burdens on the other.

CONCLUSION.

The law as definitely settled at present, then, may be summed up thus :—

1. The owner of ancient lights is not entitled substantially to the amount of light which he enjoyed before the interference ;

2. The Prescription Act of 1832 has not the effect of giving a man an absolute right to the full amount of light enjoyed for twenty years ;

3. Building operations which diminish the amount of light received by a neighbour's premises give the neighbour no right to complain so long as there is no nuisance ; *i.e.*, so long as enough light is left for the comfortable enjoyment of the premises.

Specialisation in trade today is very considerable, and the amount of light necessary varies considerably with the trade. There can be no hard-and-fast line. If your neighbour knew that for twenty years you had enjoyed an extraordinary amount of light for a particular business, it is left doubtful whether you could insist upon its continuance.

Lord Macnaghten offers a suggestion that the Court ought to have a report by an experienced surveyor for its own guidance in all these cases. That may be well for the Courts, but for the everyday working architect, surveyor, and builder it is of no assistance.

If the Surveyors' Institution were authorised by Act of Parliament to fix a standard, or if they were enabled to make an award in cases of dispute, after the manner of a referee under the Arbitration Act, much difficulty might be overcome. Or if local authorities had power, by adopting model bye-laws framed by the Local Government Board, to have a clause embodying the principles of the House of Lords' decision we have been considering, and of going a little further, and making the survey department of each local authority a court of reference in the interpretation and application of such bye-laws with a discretion, matters with regard to the right of light would be put on a sounder and more stable footing than at present. It is the duty of all interested to try and induce the Surveyors' Institution to move in the matter, and also to bring pressure to bear on Members of Parliament and members of local authorities, to take steps for settling disputes and avoiding what Lord Macnaghten calls the oppression practised by those who invoke the assistance of the Courts to protect lights they have never before considered of any value, and the oppression practised by those who are improving the neighbourhood by the erection of buildings that must necessarily interfere with the light of adjoining premises.

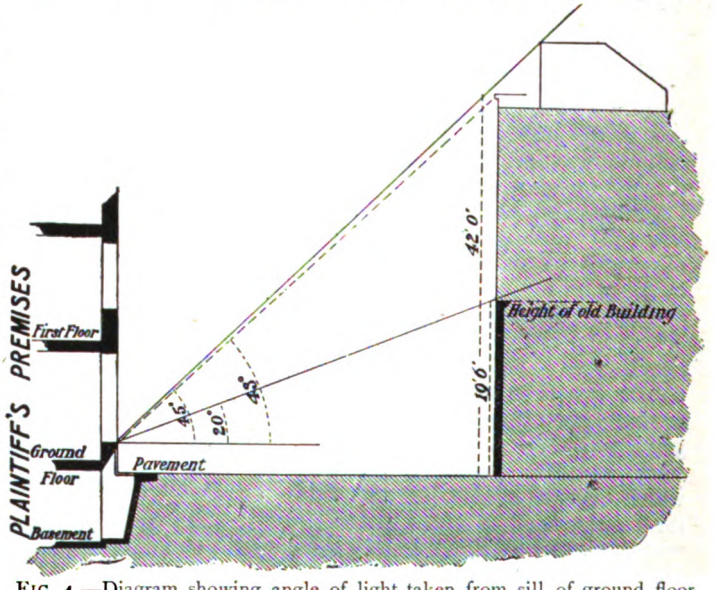

FIG. 4.—Diagram showing angle of light taken from sill of ground floor windows, 3 feet from street level, and still allowing 47 degrees of light. Angle must, however, be measured from centre of window. (See Figs. 2 and 3.)

A man engaged in a big building scheme often has to pay money right and left to avoid litigation, which will put him to even greater expense by delaying his work. This is unfortunate, and ought not to be possible unless there is a good deal of Tammanyism in what is supposed to be incorruptible English life.

Since writing the above, a case originally tried by Mr. Justice Kekewich in December, 1903, has been sent back to him by the Court of Appeal for re-trial, and he gave judgment on August 2nd. At the original hearing the judge granted an injunction to pull down a portion of the building com-

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plained of. The defendant appealed. Meantime the House of Lords decided the case of *Colls* v. *The Home and Colonial Stores*. The Court of Appeal, therefore, remitted the case for re-trial. In delivering judgment on the re-trial, Mr. Justice Kekewich said the recent decision of the House of Lords laid down a rule admittedly difficult of application, but in itself profoundly simple. In the case before him he thought there was a substantial obstruction of light to the morning room, and in a less degree to the hall. He, therefore, ordered so much of the building complained of as interfered with the access of light to be pulled down. That was his decision in law. But he ventured to offer a word of advice to both parties: to rid themselves of law and lawyers, and agree upon substantial damages; though they were not, in his opinion, an adequate remedy. If the parties decided not to appeal, he and the legal profession, and others interested, would be deprived of an instructive discussion, followed by instructive judgments.

ALUMINIUM CONDUCTORS.

ALTHOUGH the present low price of copper puts aluminium out of court as a competitor for use in cables or overhead electrical conductors, the possibilities of the case are of interest, and of some importance, in view of the fluctuations that take place from time to time in the value of the former metal. It is by no means an impossibility that copper may be forced up to the comparatively high prices that obtained a year or two ago; in which case, within certain limits, aluminium may be considered as a possible substitute.

Experience — chiefly in America — has proved that bare overhead transmission line work may, under certain conditions, be economically and efficiently carried out with aluminium, a saving in capital outlay over copper having frequently been shown. There are, however, objections to its use for this purpose that have to be considered; among these the chief is one in which local conditions play a great part. Despite numerous statements to the contrary, it has not yet been conclusively proved that aluminium is not corroded by exposure to what passes for pure air in cities; and it has been shown beyond all doubt that it is very badly attacked and pitted in situations where smoke prevails, or where the air is laden with acids, even in minute proportions. It follows that its adoption for trolley wires or other bare conductors must be guided by very careful consideration of atmospheric conditions in the actual locality; its success in the prairies of America must not be held to warrant its use in any but similar positions. As an insulated conductor it is not a commercial success, the diameter required for equal conductivity to copper being much greater, and the cost of insulation, therefore, higher; besides which, the heavier cable involves greater expenditure in every detail of laying, such as excavation, conduits, and handling.

The conductivity of aluminium varies somewhat according to the peculiarities of manufacture—sometimes iron is added in order to give increased strength—but for all practical purposes it may be taken as 60 per cent. of that of copper. Therefore, 40 per cent. more metal is required, and as the specific gravity of aluminium is 2·60 against 8·93 for copper, the weight of metal needed will be 41·6 per cent., or in round numbers 50 per cent. of the weight of an equivalent copper cable.

The present prices of high conductivity copper and aluminium wires being respectively £72 and £168 per ton, it is obvious that aluminium cannot compete; but presuming that £168 is the lowest price that aluminium is likely to reach, it only requires a rise in copper to its former value of £90 a ton, or thereabout, to render competition possible.

In comparing the relative values of the two metals for overhead line construction, it must not be forgotten that considerable economy can be effected in the pole work owing to the reduced weight of the conductor. This, however, is not a proportionate amount, as the enhanced effect of snow and wind on the larger surface has to be taken into account, and also the lower tensile strength of the wire.

The difficulty of jointing aluminium, that has always detracted from its usefulness, may be said to have been completely got over in electrical work by the adoption of various forms of mechanical joints. It has been found in practice that these are trustworthy and cheap, and preferable to soldered joints; the failure of soldered joints has contributed largely to the distrust of aluminium that prevails in this country.

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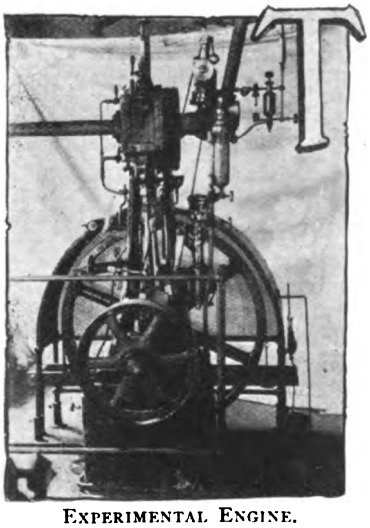
THE EQUIPMENT OF A SMALL EXPERIMENTAL STEAM ENGINE.

By HERBERT AUGHTIE, A.M.I.M.E.



EXPERIMENTAL ENGINE.
This engine has an air-cooled brake-wheel, cut-off gear which may be either made automatic or set to a fixed point of cut-off, and is fitted with a separating steam dryness calorimeter.

THAT a single demonstration will make a far deeper impression upon the human mind than repeated statements of a fact, is so fully recognised in modern systems of education that the development of illustrative apparatus in many branches of teaching is now very considerable.

Teachers of mechanical engineering, however, have often to forego this advantage when dealing with the action of the steam engine, owing to the difficulty and expense of providing so elaborate an object as an experimental engine. In the larger technical colleges, experimental engines are generally complicated and costly machines, chiefly designed with a view to research work; but for a small provincial technical school, such engines would probably be less valuable than a simple engine of moderate dimensions, which could be provided at a fraction of the expense.

It is the object of the writer to discuss the equipment and capabilities of a steam engine of this kind, which would be of the greatest service in the instruction of junior engineering students.

The first point to consider is that of size. Although useful work may be done with an engine of very small dimensions, it is desirable that the engine should be capable of developing about 10 h.p. One objection to the use of a very small engine is that in demonstrating the relationship between power developed and steam consumed at different

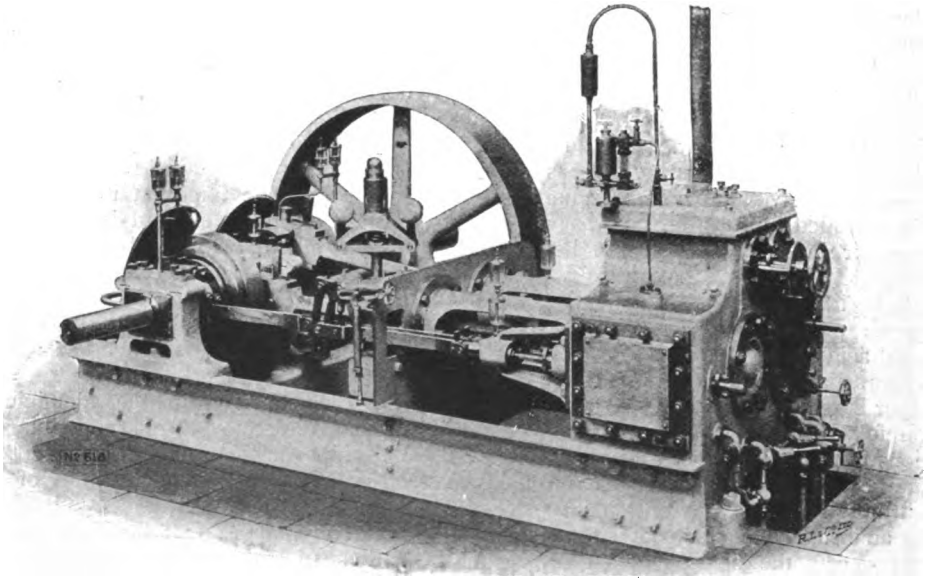


FIG. 1.—COMPOUND ENGINE.
Made by Messrs. Marshall, Sons & Co., and fitted by them for experimental work.

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loads, the smallness of the range of loads would make it difficult to illustrate the nature of this relationship clearly and convincingly, unless very accurate measurements were made. This disadvantage would also occur in showing how the mechanical efficiency varies with the load. On the other hand, the choice of too large an engine would involve enhanced steam consumption, greater cost of maintenance, and more elaborate means of absorbing the power, for all of which no commensurate advantage would be gained.

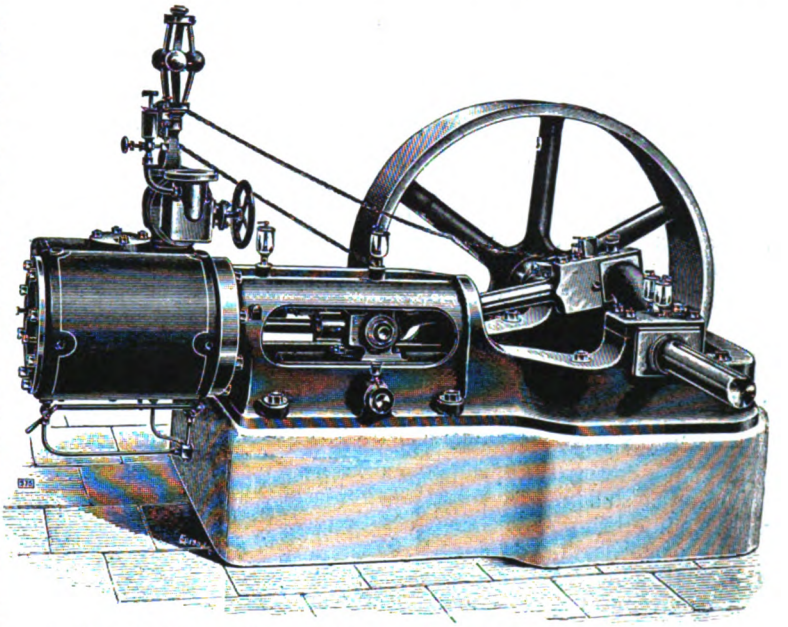

FIG. 2.—SELF-CONTAINED SIMPLE ENGINE FOR SMALL POWER. By Messrs. Marshall, Sons & Co.

As regards type, practically all engines which develop no more than 10 h.p. are designed to be self-contained, so that the expense of erection is at a minimum; but a choice may be made between vertical and horizontal engines. Where space is restricted, it may be better to instal a vertical engine; but when this is not the case, a horizontal engine is, in the writer's opinion, preferable, on account of the inconvenient height at which the indicator has frequently to be fixed on a vertical engine. The vertical engine can, however, be conveniently arranged to work an air pump by means of a rocking lever.

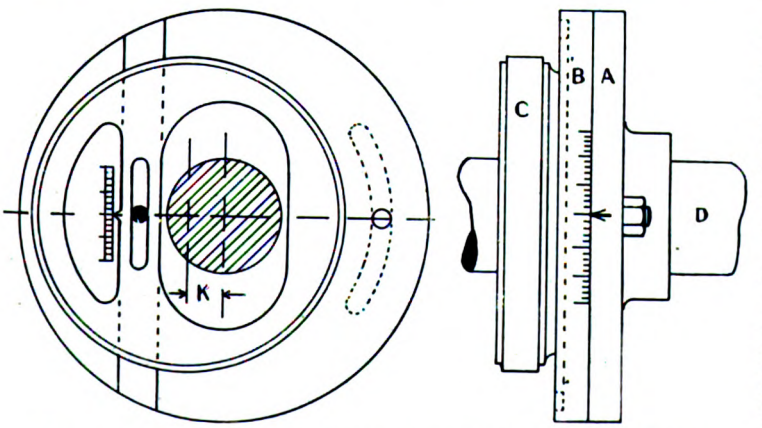

FIG. 3.—ARRANGEMENT OF ECCENTRIC TO VARY LENGTH OF TRAVEL AND ANGULAR ADVANCE.

A—Circular plate keyed to crank-shaft.
B—Circular plate loose upon crank shaft and fastened to the plate A by a stud passing through a curved slot in the plate A.
C—Eccentric—provided with a feather to fit a groove on the plate B and fastened to the plate B by a stud passing through a slot in the eccentric.
D—Crank shaft.

The rotational speed should not be too high, as a high speed leads to inconvenience and difficulty in taking indicator diagrams. Anything between 150 and 200 revolutions per min. is a suitable speed.

It is of the highest degree of importance that the governor should be extremely stable, for if "hunting" takes place the indicator traces a series of overlapping diagrams from which it is impossible to deduce a correct estimate of the power developed. The greater the degree of stability, the greater will be the range of

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speed variation permitted by the governor; this, of course, is not desirable, but is a minor evil. If the engine is provided with a cut-off governor, this should be so arranged that it may be rendered inoperative when desired.

A valve gear which allows the point of cut-off to be varied at will, whilst disturbing the steam distribution in other respects as little as possible, is a most desirable feature. The Meyer slide valve answers these requirements satisfactorily, as the velocity of the valve at the point of cut-off varies little over a considerable range, whilst the points of admission, release, and compression are not varied at all.

The valve gear should be capable of being deranged and adjusted without removal of the steam chest cover; since, with the aid of the indicator, a student may thereby gain much valuable information respecting valve setting.

The arrangement shown in Fig. 3 supplies a means whereby different lengths of travel may be given to the slide valve, and different angles of advance to the eccentric. The eccentric may be adjusted to give various points of cut-off, whilst preserving a constant amount of lead, by shifting it across the intermediate plate, but it is inferior to a Meyer valve, since the points of compression and release do not remain constant. Assuming the arrangement to be fitted to a horizontal engine, then, when the piston is at the commencement of its stroke the line joining the eccentric centre to the shaft centre will make an angle α to the horizon, such that the travel of the valve will always be $2K \sec \alpha$, where K is the least possible distance between these centres, and the corresponding angular advance is $90 - \alpha$. This relation holds when the groove in which the eccentric slides is at right angles to the engine centre line; but if, after fastening the eccentric to the intermediate plate, the latter be turned round the shaft in a forward direction, and fixed so that the groove is at an angle θ with its initial position, then the angle of advance becomes $90 - \alpha + \theta$ without further variation of the travel.

The joint between the eccentric rod and the valve spindle should be so formed that the valve may be moved along the valve face independently of the eccentric.

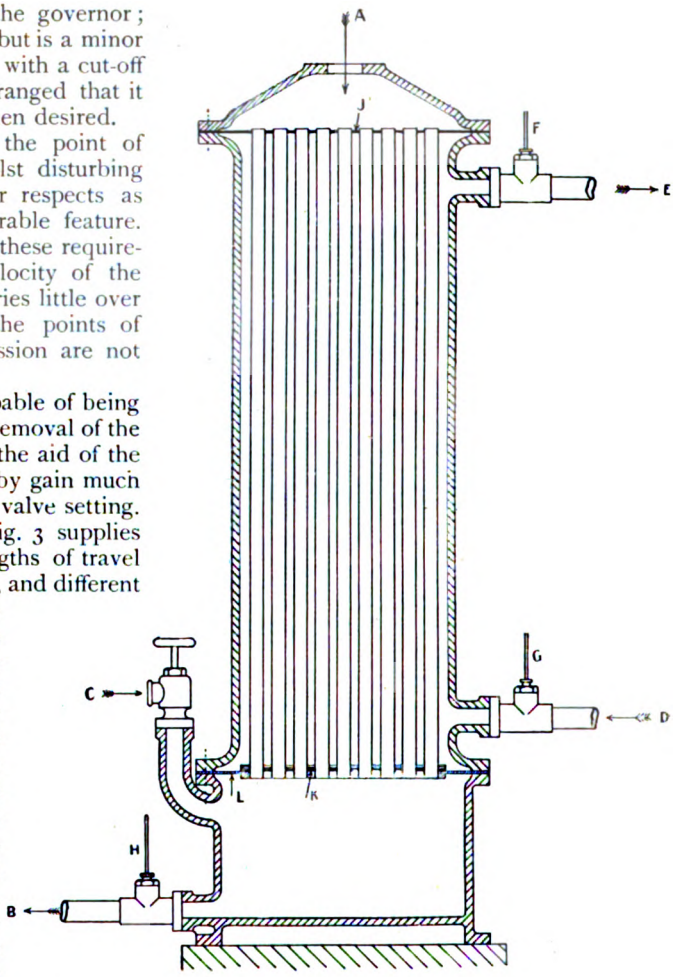

FIG. 4.—SURFACE CONDENSER.

A—Inlet for exhaust steam.
B—Outlet for condensed steam.
C—Valve for the admission or exclusion of the atmosphere.
D—Cooling water inlet.
E—Cooling water outlet.
F, G and H—Thermometers.
J—Flexible brass plate in which the condenser tubes are soldered.
K—Brass plate in which condenser tubes are soldered. This plate is sufficiently small in diameter to pass through the body of the condenser.
L—Flexible brass plate, connected by screws to the plate K.

Whatever form of valve gear is used, it is useful to have sectional models of the valves connected to the valve spindles; these, in conjunction with a sectional model of the valve face, allow the various movements and settings to be studied without removal of the steam chest cover.

For some experiments, certain dimensions of the engine are necessary which cannot be obtained very conveniently when the engine is equipped for running. The clear

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ance volume at each end of the cylinder, the weight of the piston and piston-rod, the weight of the connecting-rod, the diameters of the piston and piston-rod, and the length of the stroke, should therefore be ascertained at the time of erecting the engine, and carefully recorded. Some of these dimensions (without breaking a steam-joint) may, and should, be determined by a student, but it is may be conveniently measured. Under practical conditions, the object of the condenser is to provide a means whereby the effective pressure of the steam upon the piston may be increased; and when this is done an air-pump is required to remove vapour, air, and condensed steam from the condenser.

Although, for experimental work, the condenser is necessary, yet the air-pump is not

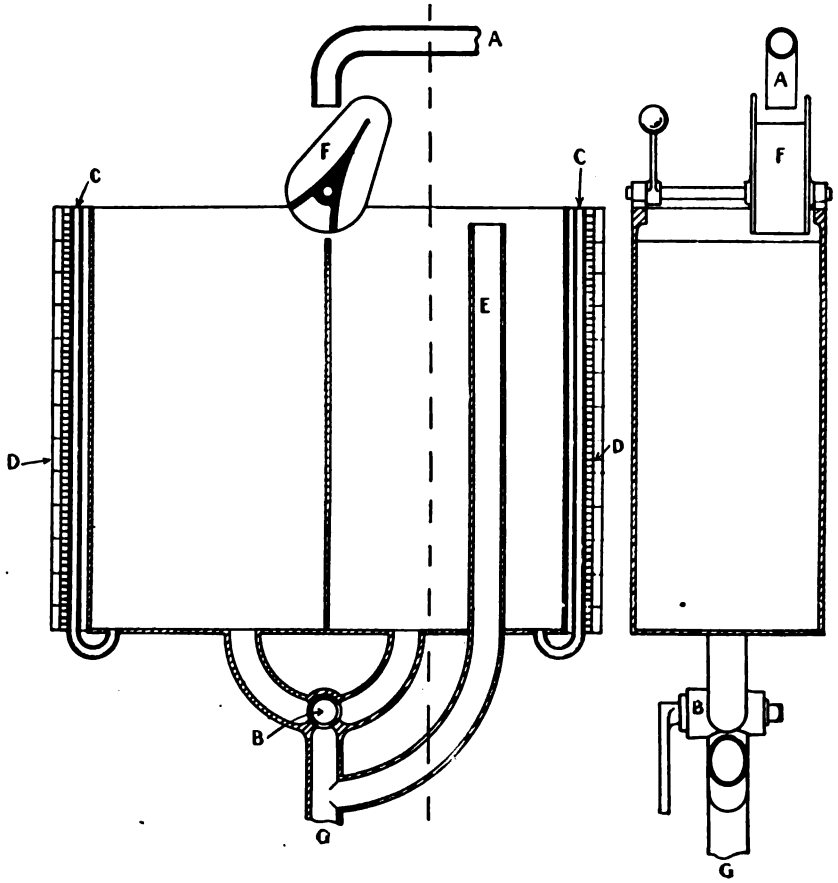

FIG. 5.—TANKS FOR MEASURING CONDENSED STEAM.

A—Delivery pipe from air pump.
B—Three-way cock.
C C—Glass tubes to indicate the height of water and connected to the tanks by return bends and india-rubber tubing.
D D—Scales formed by calibrating the tanks to indicate the quantity of water in the tank.
E—Overflow pipe.
F—Deflector, fixed to a rocking spindle.
G—Delivery to drain.

convenient to have them accessible when the engine is running.

One of the most important measurements to make in experimental work is the determination of the quantity of steam consumed. The best way to do this is to eject the exhaust steam into a surface condenser. From the condenser the condensed steam may be transferred into tanks, where its volume or weight indispensable, for by allowing the atmosphere to communicate with the condenser the condensed steam is enabled to gravitate into the measuring vessels. In this case the engine is, of course, working under the same conditions as if the exhaust were simply ejected into the atmosphere. If, however, the engine is furnished with an air-pump, a valve should be fitted to the condenser, whereby the

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atmospheric pressure may either be admitted to the condenser or not, as desired. The degree of vacuum is shown by a gauge which is in connection with the condenser.

A jet condenser is unsuitable for experimental work, since the cooling water and condensed steam mingle together in the condenser, which would cause a difficulty in measuring the quantity of steam consumed. In attaching an air pump to a horizontal engine, an eccentric or a crank disc may be employed to drive the pump; the eccentric is preferable, as the end of the crank shaft is then left free for the operation of a hand speed counter.

The quantity of cooling water required for an engine of anything but the smallest size is considerable, and this fact should be borne in mind when arrangements are being schemed for the measurement of water used.

The following method has proved very successful. A pipe of fairly large diameter is erected vertically above a drain; the top is open, the bottom closed by a plate in which a number of holes are drilled. The cooling water issuing from the condenser is carried into the pipe by a smaller pipe, which has its lower end stopped, but containing a large number of small drilled holes. The rate of flow of the water through the holes in the plate is then a function of the head of water in the pipe. The pipe may therefore be calibrated, and a scale made to indicate the rate of flow of the water. In order to observe the head, a glass tube is placed near the scale, which is in communication with the body of water in the pipe.

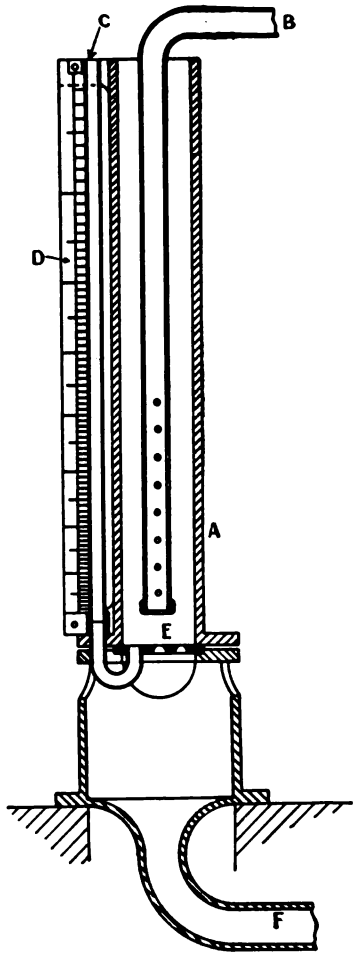

FIG. 6.
APPARATUS FOR MEASURING THE FLOW OF COOLING WATER.

A—Cast-iron pipe, flanged at the base.
B—Delivery of cooling water from the condenser.
C—Glass tube connected to the pipe A to indicate the water height.
D—Scale showing flow of water in lbs. per minute.
E—Brass plate containing from 4 to 8 drilled holes.
F—Delivery to drain.

For the measurement of the condensed steam, it will be found that a suitable arrangement consists of a pair of calibrated tanks, placed side by side at a convenient height. The delivery from the air pump may then be directed into either tank by fixing a piece of flexible pipe on the end of the delivery pipe, or by means of a rocking deflecting plate. If, then, one tank is emptied whilst the other is being filled, the amount of steam used during an experiment of unlimited duration may be accurately measured. Measurement by weighing is certainly more correct in principle than volumetric measurement, since the condensed steam is not delivered into the measuring tanks at a constant temperature; but the latter method is usually simpler and more convenient. Moreover, corrections may be made for variations in density. In order to calibrate the measuring tank, weighed quantities of water are poured into it, the height of the water in a glass tube connected to the tank and the quantity of the water being marked on a scale after each increment.

In order to render the steam used by the engine as dry as possible, a good-sized separator provided with a steam trap must be fitted as near as possible to the steam chest, and to test the degree of dryness, some form of dryness calorimeter should be used. If the separator is efficient, this may be done to a high degree of accuracy by means of a throttling calorimeter.

The action of Carpenter's Separating Calorimeter is, however, much more easily grasped by a junior student. By means of this instrument the dryness fraction of extremely wet steam may be determined, which cannot be done with the throttling calorimeter. The educational value of the plant would be increased if both, instead of one, of the two types were fitted up.

The determination of the effective horse-power of a small engine does not necessitate elaborate arrangements. A very simple brake

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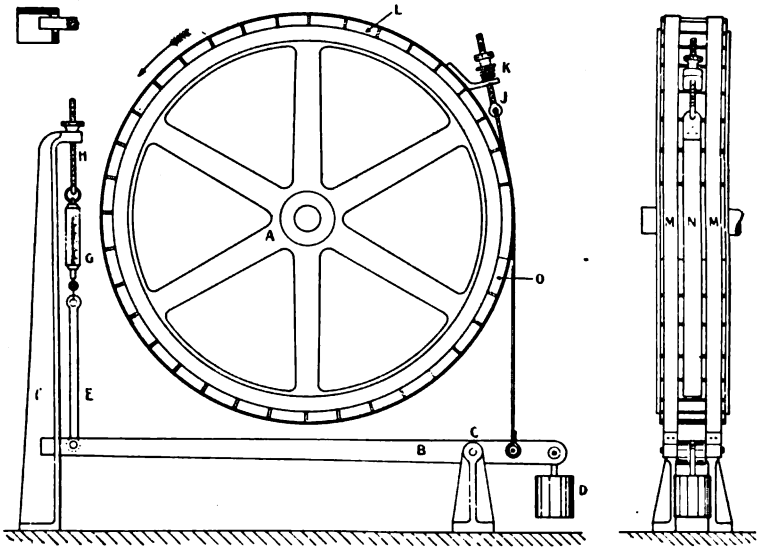

FIG. 7.—ABSORPTION DYNAMOMETER.

A—Fly-wheel with shallow flanges.
B—Wooden lever.
C—Ball bearing forming the fulcrum of the lever.
D—Weight to counterpoise the lever.
E—Link connecting lever to spring balance.
F—Cast iron standard to support spring balance, provided with a slot near the base to limit the movement of the lever.
G—Spring balance.
H—Adjusting screw to compensate for the extension of the spring balance.
J—Adjusting screw to compensate for wear of brake blocks, and to regulate the grip of the brake.
K—Spiral spring interposed between adjusting nut and bracket on brake block.
L, L, L—Wooden brake blocks.
M M—Flexible bands (leather or brass) fastened to brake blocks, attached to the lever, passing round the wheel and terminating at the block O.
N—Short flexible band fastened to brake blocks at its lower end and connected to the adjusting screw J at its upper end.
P—Horizontal section through the standard F at the level of the lever B.

dynamometer is constructed by coiling a rope around the fly-wheel, attaching weights to one end of the rope, and fixing the other end to a spring-balance, which is anchored to some convenient point. Some degree of experience is required to ensure successful working, for it is quite possible for an unskilled person to have the weights whirled around the wheel; whilst if the engine be stopped before the brake is disconnected, the probable result will be fracture of the spring-balance. A rope sometimes causes trouble by being insufficiently flexible. For anything but the smallest size of engine, some such arrangement as that shown in Fig. 7, which permits of safe, easy, and rapid variations of the load, is generally preferable. Instead of passing under the wheel, the lever B may be suspended to a girder above the engine, and the loading of the long arm may be done by weights instead of a spring-balance. In one form, which has given satisfactory results, the end of the long arm was attached to a cord wrapped around and fastened to a small pulley mounted on a ball bearing. A heavy pendulum fastened to the pulley was deflected by the pull of this cord, and a pointer attached to the pendulum indicated on a scale the resistance of the brake. It is quite obvious that the best lever ratio is 10 for the arrangement shown.

In a laboratory where several engines are installed for experimental purposes it is not advisable to provide identical measuring apparatus for each; and where only one is available, it is worth while to have more than one arrangement. As all the work done by an engine is transformed into heat when a brake dynamometer is used, the heat thus generated must be disposed of by some means. With very small engines there is no difficulty if the fly-wheel is used as a brake-wheel, as all the heat produced is readily dissipated by air-cooling; but water-cooled brake-wheels are necessary for powerful engines.

If the product of the diameter and the breadth of the brake-wheel, in inches, is not less than twenty-four times the horse-power

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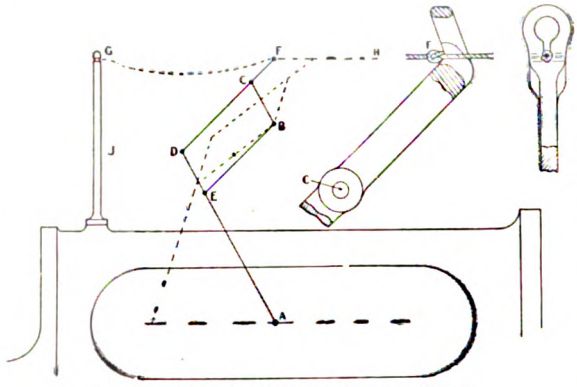

FIG. 8.—PANTAGRAPH REDUCING GEAR.

A—Cross-head pin.
B—Fixed centre formed on a bracket attached to the engine frame.
C, D, E—Joints of the pantagraph.
F—Point of attachment of the cord.
G, F, H—Indicator cord. If the cord is in gear, then by lifting it at the slack part G F the knot in the cord is enabled to pass through the large part of the eye at F, thus disconnecting the indicator. The indicator is connected to the reducing gear by pulling the slack part until the knot has passed through the eye.
J—Column to which the slack end of indicator cord is attached.

developed by the engine, the air may be relied upon for cooling the wheel; whilst for water-cooled brake-wheels the product of the breadth and the diameter should not be less than about five times the horse-power of the engine.

The kind of indicator reducing gear chosen must depend to some extent upon the form of the engine. The pantagraph type is kinematically perfect, but the joints of the links are liable to wear. Whatever type is adopted, some device should be employed by means of which the cord may readily be connected to, and disconnected from, the reciprocating parts of the engine, whether the engine is running or not.

If no such device is provided, the indicator drum must be stopped by seizing the moving cord, and the paper-drum removed in order to remove and replace the cord.

Although this is easy enough for an expert operator, yet it is much better, in the case of inexperienced students, to avoid it in the manner suggested.

For the measurement of the thermal quantities involved in engine experiments a number of thermometers are required. Some of these are used to ascertain the temperature of steam which may have a considerable pressure, and in this case the thermometer is inserted in a small iron or steel pocket containing mercury, which is arranged to dip well into the current of steam. Gun-metal or brass cannot be used in conjunction with mercury, as amalgamation would result.

Those thermometers which are used to obtain the water temperatures may be arranged to have their bulbs in direct contact with the water, if they are passed through stuffing boxes fitted on one branch of a T piece inserted in the line of piping. It is desirable that the thermometers should be protected from injury by being enclosed in brass cases.

Thermometers should be fitted so that the following temperatures may be obtained: *viz.*:—the temperature of the cooling water just before entering, and just after leaving the condenser; the temperature of the condensed steam as it leaves the condenser; the temperature of the exhaust steam; and, if a throttling calorimeter is used, the temperature of the steam before and after superheating.

Rotational speed may be found either by a tachometer, a fixed speed counter, or a hand speed counter. If it is required to obtain the speed as quickly as possible, which in some cases is desirable, a tachometer is most convenient. Various types of this instrument are manufactured, but an efficient arrangement, which may be

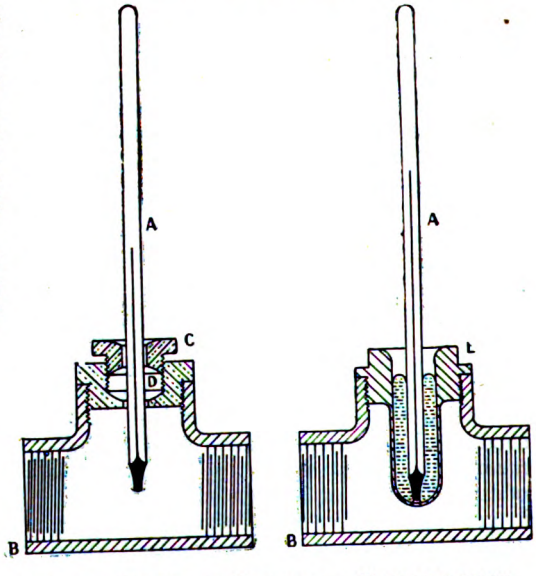

FIG. 9.—METHOD OF FITTING UP THERMOMETERS.

A A—Thermometers.
B B—T-pieces.
C—Brass gland with milled head.
D—Stuffing box.
E—Steel or iron pocket containing mercury.

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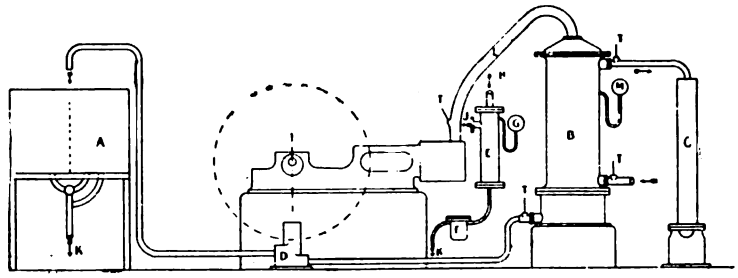

FIG. 10.—GENERAL ARRANGEMENT OF EXPERIMENTAL PLANT.

A—Measuring tank for condensed steam.
B—Surface condenser.
C—Measuring apparatus for cooling water.
D—Air pump.
E—Separator.
F—Steam trap.
G—Pressure gauge.
H—Separator inlet.
J—Separator outlet.
K K—Delivery to drain.
L—Exhaust pipe.
M—Vacuum gauge.
T, T, T, T—Thermometers.

fitted up at a small cost, consists of a very small centrifugal pump driven from the engine crank shaft, which forces water up a tall glass tube. The height to which the water will rise in the tube is a function of the speed of the pump, and hence of the engine. A scale may therefore be determined and fixed to the tube, to indicate the engine speed in revolutions per minute. A fixed speed counter giving progressive readings is extremely trustworthy and convenient, but hand speed counters cost little, and should always be provided.

In Fig. 10 is shown diagrammatically an arrangement of an experimental plant consisting of the elements which have been described. The actual arrangement will, of course, depend upon circumstances, but several important points should always be attended to. If the plant is to be used for the purpose of demonstrating before a large class, an arrangement resembling that given in the figure should be provided, in order that a view may be obtained of all the apparatus and manipulations by the members of the class without change of position on their part.

If, however, facilities are required only for individual experimenters, working independently at the various elements of the plant, the arrangement shown may be varied considerably without inconvenience, but ample space should be provided at every place where observations are to be made. In either case, the arrangement of the pipes, thermometers, valves, etc., should be such that their respective functions may be easily understood, and this will be greatly assisted if plainly printed labels are attached to these details, stating the purpose for which each is employed.

Light tables and brackets for resting books or log-forms upon, whilst observations are being recorded, are necessary; and when the plant is used for demonstration, a blackboard, ruled with horizontal

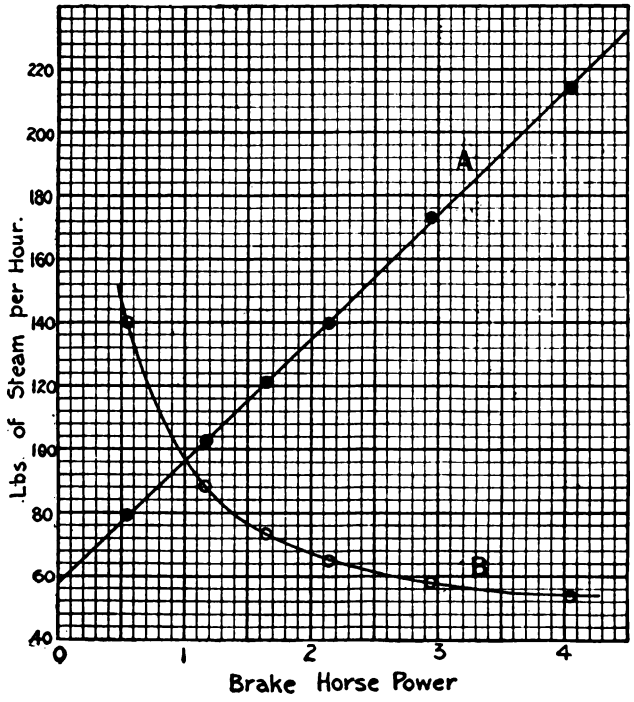

FIG. 11.

A—Curve showing number of lbs. of steam per hour consumed by an engine.
B—Curve showing number of lbs. of steam per B.H.P. per hour

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and vertical lines, so as to divide up its surface into squares of about one inch side, is extremely useful for plotting results upon. It is best to use red paint in forming these lines. Scale drawings, showing sections of the engine and the condenser, should be mounted and kept near the plant.

Great care should be exercised in securing sound workmanship in every detail, and adequate fencing should be provided at every point where there is any possibility of danger; for there are many parts of a high-pressure steam plant the failure of which would, in a crowded laboratory, lead to very serious results.

Assuming that such a plant as that described is available, the following experiments may be carried out by junior students:—

Determination of rate of steam consumption.—If calibrated measuring tanks are provided to receive the condensed steam, a series of readings of the water level, and the times of observation, may be plotted on squared paper, when the required rate may be found from the slope of the curve.

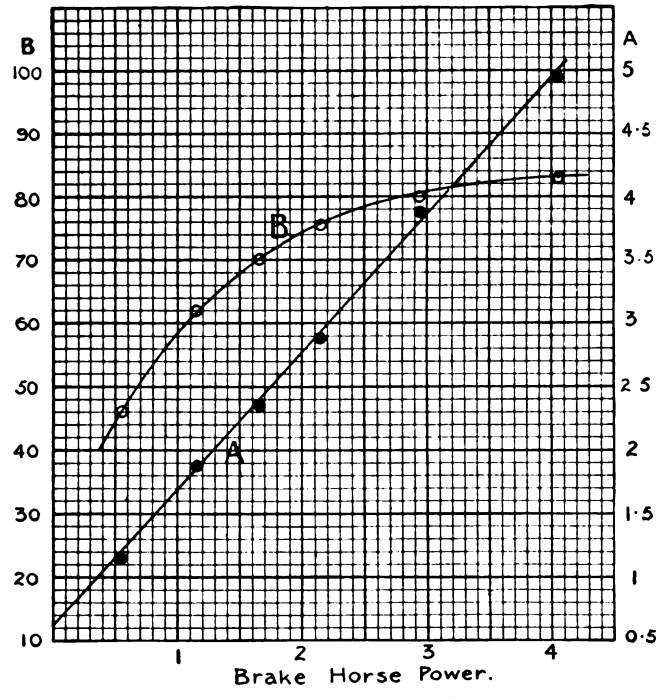

FIG. 12.

A—Curve showing relation between I.H.P. and B.H.P.
B—Curve showing percentage mechanical efficiency at different loads.

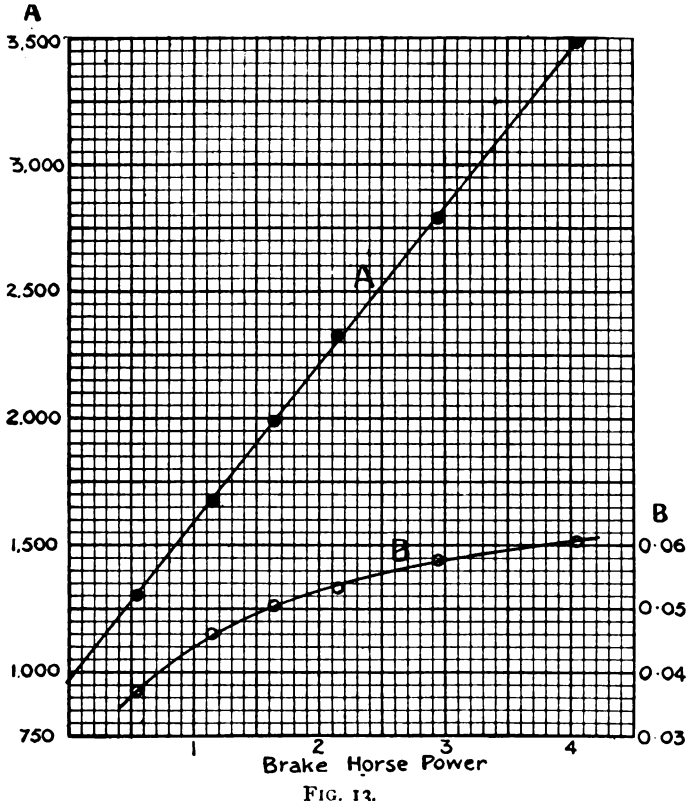

FIG. 13.

A—Curve showing net heat supply to an engine in B.T.U.s per minute.
B—Curve of thermal efficiencies at different loads.

Determination of the rate of heat flow into the cooling water.—A series of observations of the rate of flow of the cooling water through the condenser, and the temperatures of the cooling water at the inlet and outlet, are obtained and averaged. The required rate may then be easily deduced and expressed in British thermal units per minute.

Determination of the number of British thermal units per lb. of steam entering the engine, which pass into the cooling water.—This may be found by obtaining the number of lbs. of steam used by the engine, and the number of British

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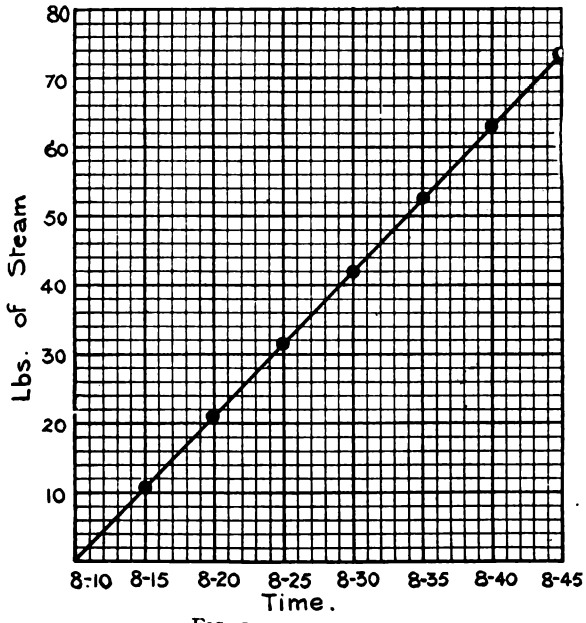

FIG. 14.

Curve showing the rate at which steam is consumed by an engine.

thermal units passing into the cooling water during any interval of time. It is instructive to a junior student to compare the quantity of heat thus disposed of with the total quantity of heat initially possessed by the steam.

Determination of the amount of heat possessed by the condensed steam as it leaves the condenser:—The steam consumption is determined, and a series of observations of the thermometer, fitted at the condensed steam exit from the condenser, is obtained and averaged. From these data the required result is obtained.

Effective or brake horse-power.—The necessary data are gained by finding the speed of the engine and taking readings of the forces acting at either end of the brake-strap, together with the distances of their lines of action from the centre of the brake wheel.

Steam consumption per B.H.P. per hour.—This may be found when the B.H.P. of the engine and the simultaneous rate of steam consumption are determined. It is instructive to find this quantity for various rates of working and to plot the results. By plotting the total steam consumption per unit of time at various loads upon a horse-power base the straight line curve known as "Willan's line" is obtained.

Indicated horse-power.—Indicator diagrams, the scale of the indicator spring, the diameters of the piston and piston-rod, the length of the stroke, and the speed of the engine are the data required.

Mechanical efficiency may be found when the B.H.P. and I.H.P. simultaneously developed are known. The mechanical efficiency at various rates of working should be determined and plotted upon its power base.

Thermal efficiency.—This is determined by finding the number of ft.-lbs. of work done by, and the number of thermal units supplied to, the engine per unit of time. The required efficiency is the ratio of the first quantity, to the second multiplied by Joule's equivalent.

The most economical load is determined by finding a sufficient number of points in a curve such as B, Fig. 11.

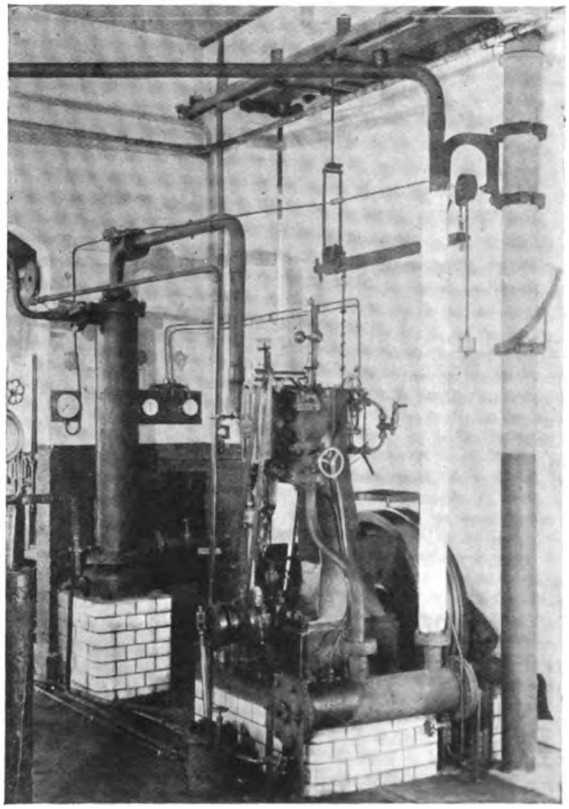

FIG. 15.—EXPERIMENTAL ENGINE.

The figure shows the separator, steam trap, air-pump, surface condenser, Ripper's mean pressure indicator, and brake lever attached to a pendulum passing over a scale.

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The point of the curve which has the shortest ordinate indicates the required load.

The most economical point of cut-off is found by obtaining the steam consumption per B.H.P. per hour at different points of cut-off, and plotting them on a base showing points of cut-off. The required point is that at which the vertical ordinate is smallest.

The economy due to the use of a condenser and air-pump may be found by performing two experiments with like conditions in each, except that in one of them the air valve on the condenser is closed, whilst in the other it remains open.

The most economical degree of vacuum in the condenser may be found by regulating the air valve to allow a certain amount of leakage into the condenser to take place. A number of experiments are then made with a constant load upon the engine, and the steam consumed per B.H.P. per hour is plotted upon a base which shows the number of lbs. or inches of vacuum. The point required is that at which the ordinate is least.

The following is a sample heat balance sheet obtained from a small engine fitted up in the manner described :—

Heat received by Engine.		Heat disposed of by Engine.	
	B.T.U.		B.T.U.
Total heat of the steam supplied per min. .	5850	Heat given to cooling water per min. .	5400
		Heat in water taken from the hot well per min.	200
		Heat equivalent of work done per min. .	228
		Heat unaccounted for	22
	5850		5850

If we know the rate at which steam is being consumed, the initial temperature and dryness fraction of the steam, and the dimensions and speed of the engine, the indicator diagram will afford considerable information as to what is happening to the steam during its passage through the engine ; but a correct deduction cannot be made unless arrangements are made for measuring the amount of leakage past the valves and piston rings. This may be done by fitting up an arrangement which will enable the fly-wheel to be locked at various points of the piston-stroke, blocking the exhaust pipe and carrying a pipe from the drain cocks of the cylinder to a condenser.

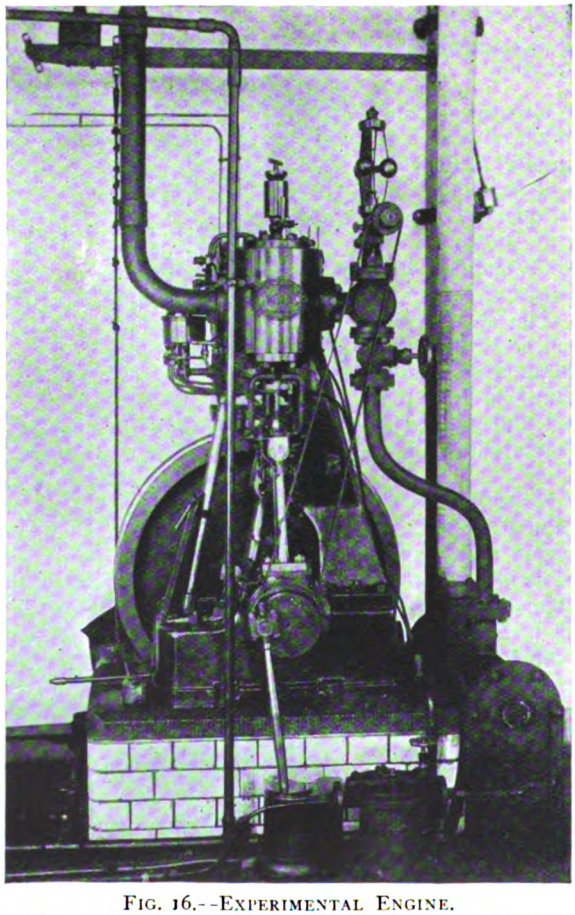

FIG. 16.—EXPERIMENTAL ENGINE.
This is another view of the engine represented in Fig. 15, which shows the water-cooled brake wheel.

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TECHNICAL EDUCATION IN RUSSIA.

By JOHN HULME, F.C.S.

A LITTLE while ago, whilst travelling in Russia, it was my good fortune to become a guest in, as well as visitor at, the palace of the Tsar; and, from a conversation I one evening had at dinner there, my attention was attracted to the question of the Muscovites' position in regard to technical education. The results of the investigation I subsequently undertook were decidedly interesting. I found the Tsar himself to be right in the front rank of the champions of technical education in Russia. Through him, a goodly portion of the profits from the Government whisky monopoly has been set aside for educational purposes; and his influence has been all along placed on the side of the science men in their victorious struggle with the classicists.

It may as well be confessed that the old jest as to Gortschakoff's ideal Russia—a highly-educated aristocracy, an officially mis-taught middle class, and a totally illiterate populace—has lost its force to-day; for the last twenty-five years have wrought so great a change in Russia's scholastic system, that it may now justly be set on a plane higher altogether than that which it occupied in the seventies of last century. Illiterate, it is true, her populace still is, judging from an Imperial Commission report issued about ten years ago, which states that "scarcely a man out of every four could read, whilst over 3,000 schools would have to be erected annually, for a great many years, before the means of education were placed within the reach of every child in the Empire." Still, it only requires a short residence in the country to discover that we must affix the mark of excellence to the scholastic attainments of what one might regard as her middle class. Furthermore, besides having made creditable progress in secondary education, she also seems, at last, to have satisfactorily solved what has been, for her, the hitherto baffling problem of technical education.

One might be excused for taking a special interest in her work in this direction, since, although Germany is the name usually associated with technical education, yet Russia may be regarded as one of its pioneers; and there are many Americans to-day who, looking upon Moscow as the cradle of the well-known Massachusetts Institute, are always ready to render tribute to the Russian example of bygone days.

It must be confessed, though, that from Peter the Great's time until recently, Russia's efforts to increase the skill of her workmen had been followed by comparatively poor results; yet she appears never for a moment to have swerved from her object, but, benefitting by her mistakes, to have learnt the paradoxical lesson that nothing is so successful as failure.

Her educational specialists, in their quest for knowledge, have explored every civilised country. They were to be met in Paris, studying travelling scholarship schemes for commercial students: in Germany, investigating the results achieved by Professor Beyer and his colleagues: taking notes at Zurich: playing the scholastic observer in London, Manchester, or Leeds; and I myself have encountered them even seeking inspiration so far away as the Southern States of America. As a result, Russia now has the satisfaction of having developed a system of instruction which, although still leaving something to be desired, exhibits much to challenge our approval, and not a little that we might profitably imitate.

Her present position in the field of technical education may, perhaps, be interestingly illustrated by instituting a comparison between her past industrial methods and those of England—methods diametrically opposed one to the other. England had pinned her faith to the man at the bench: Russia had sought laurels by making a hero of the man with the book. John Bull had centred his energies on the education of the hand: Ivan had concentrated his on the cultivation of the head. At one end of the scale, the English craftsman stood as the embodiment of digital dexterity; at the other was the Russian, personifying theory.

Mill, workshop, or warehouse management was the goal of the Muscovite industrial student's ambition; but he believed it was a goal he could only reach by a long march across fields of physical formulæ, and mountains of mathematics. Consequently, his

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disappointment was keen on finding that he was always outpaced, either by some English mechanic, perhaps ignorant of the binomial theorem; or, maybe, some calculi-less English weaver.

If theory, alone, could have established the supervisional supremacy of the Russian in his own country, then, long ago, might Ichabod have been written over the English colonies in St. Petersburg and Moscow; for the theoretical instruction imparted to students at any of the great technological institutes of the Empire has always been of a quality that could not elsewhere be excelled.

Indeed, it is impossible to visit one of these huge establishments at St. Petersburg, Moscow, Karkof, Tomsk, Riga, Warsaw, and Kief, without being forcibly impressed by the intense efforts of Russia to supply, and at the same time even to raise the standard of, the skilled labour for her home market.

In the early part of this year it was my privilege to be brought into contact with M. Galovin, Director of the Imperial Technological Institute, St. Petersburg; and under his guidance I was enabled to make a very detailed examination of the foundation upon which the inhabitants of the Russian capital had built such exalted hopes—hopes, it is true, that have never been fully realised, though the reason for this has lain in the ideals of its students rather than the equipment and curriculum of the Institute itself.

Eighteen is the age at which a youth can enrol himself here, and on the completion of his five years' course he graduates as a "technologue" in either mechanics or chemistry (special institutes exist for teaching those who desire other work). During the first year of study there are certain subjects studied by all:—mathematics, political economy, natural history, mineralogy, and drawing. A knowledge of mathematics up to trigonometry and analytical geometry is required from beginners, and study of the differential and integral calculus is finished by the end of the second year.

Candidates for the mechanical diploma, besides spending more hours in the workshop than students who intend to specialise in chemistry, also devote extra time to drawing, and some of the work done by them in their last year is of exceedingly high quality; the specimens selected at random by myself, which I was permitted to bring away with me, having since received the warmest praise from some of our foremost advocates of technical education, who have frankly confessed that, whatever other result may have been achieved, Russia's endeavours in this direction have succeeded in making a first-class draughtsman of Ivan.

The general course of tuition in inorganic and organic chemistry, as well as chemical physics, extends over three years, the student being then expected to begin original research; at the end of the second year (in addition to making use of the Institute's applied chemistry plants for tar distilling, soap boiling, oil refining, etc.), students commence a round of visits to works in the neighbourhood, for the purpose of obtaining an acquaintance with the manufacturing side of their subject. Altogether, about 200 pupils can be accommodated in the General Chemistry laboratories, the equipment of which is superior to that of many of our front rank technical schools, and equal to that of any of our universities.

Class-room lectures and demonstrations are supplemented, on the mechanical side, by work at the bench, pattern making, erecting, and moulding; and experience of further phases of engineering is gained by means of a capital series of drilling, slotting, screwing, and polishing machines obtained from England, Cincinnati, Rhode Island, Hanover, and Sweden: it is no unusual thing to see, in one room, 100 young men engaged at the vice.

In addition to a dynamo capable of producing a current of 800 amperes, the Institute possesses a 400-h.p. engine which may be worked either as a triple expansion, compound, or single engine and condenser; and the usual arrangements are also made for investigating the amount of coal burnt, water used, condensation, and other matters connected with the working of a steam engine.

The ability of the students to make a water-pipe valve—the test of previous training that students approaching the end of their course, here, usually undergo—would be deemed, by a practical mechanic, to be very satisfactory; for this part of their work, the graduates find a constant market among the various Russian water companies.

But the knowledge-acquiring facilities at the disposal of the budding technologue have not yet been fully enumerated:—In an immense scientific library of 100,000 volumes can be found a copy of every book of any authority on technology; the adjoining room contains the world's principal scientific magazines and reviews, among which are to be noticed the *Journal of the Chemical Society*, *Chemical News*, *Nature*, *Engineering*, *Scientific American*, and the *Journal of the American Chemical Society*, &c.

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Time spent among the multitudinous models in the Machinery Hall enables a student to become familiar with the construction of bleaching, dyeing, textile, and agricultural machines: ventilating engineering appliances: electro motors, cranes, hydraulic pumps, stores, railway bridges, stationary steam engines, and locomotives; and should he likewise be desirous of acquainting himself with what is taking place in the domain of chemistry and mineralogy, he has only to turn his steps towards the Museum, the numerous shelves and cabinets of which are most plentifully laden with specimens of raw materials and manufactured products from every quarter of the globe.

The students are drawn from a wide area, the poverty of many of them being exceedingly great. Nevertheless, their enthusiasm is unbounded, and the self-sacrifice they are willing to undergo for the sake of acquiring knowledge calls for the highest commendation. It is consequently gratifying to find that the cost of their education is lessened by a grant of £2,000 a year towards the expenses of the Institute's kitchen and dining room; thus enabling the authorities to, daily, supply appetising stews, roasts, and other dishes at less than the cost of the raw materials—a good two-course dinner being provided for sixpence.

From the above, it will be acknowledged that elaborate provision has been made for teaching the Russian student the scientific principles underlying his trade, plus a little practical knowledge of it; and had he graduated imbued with the necessity for afterwards considerably increasing his practical skill - the necessity for going through the mill in a real, as well as a figurative sense—there would have been nothing to prevent him from distinguishing himself in the artisan world.

But this was not exactly his ideal. To him the high water-mark of technological excellence was represented by a college diploma, possessed of which, all further striving after efficiency was needless. With it, all things were to be possible; and it had only to be brandished in the face of an alien foreman or manager in order to fill him with a sense of inferiority, and cause him at once to beat a retreat from the supervisional field. Indeed, it might be facetiously yet truthfully said that the "technologue" quitted his Alma Mater, an *engineering essayist steeped to the eyes in geometry, skilled in drawing, and an authority on water-pipe valves.*

His tutors, farther seeing than he, and realising the imperativeness for his acquiring additional training in the practice of his trade, counselled him to spend his summer vacations in one or other of the works throughout the country: to make full notes of what he did and saw done there; and on the reassembling of class the following winter, to submit his notes for inspection and criticism.

This was an interesting experiment; but although the firms influenced by Russian capital were numerous enough to ensure its performance, yet, after a short time, there became evident a decided feeling of reluctance to admit these students-in-training, owing to the disorganisation their presence created in the various mills and workshops.

Despite the previous pecuniary struggles of many of them, they considered themselves to be of a totally different mould from the ordinary workman: could not realise even the possibility of being able to learn anything from a man ignorant of logarithms; and considered it derogatory to accept any instruction from him. Consequently, it will not cause surprise to learn that, for a long time, masters and managers refused to admit them into their works at all.

Occasionally, however, patriotism getting the better of business discretion, would go so far even as to give the control of a concern to a "technologue"; an event usually followed by vanishing dividends, leading ultimately to the native manager's supersession, and the granting of a huge salary to the foreigner who was sent for to replace him.

"Yes," said a certain Russian manufacturer, "our men are capital theorists: none could be better. Still, it has taken many years to teach them the lesson that, for industrial purposes, class-room excellence is of itself insufficient, but ought to be accompanied by a corresponding amount of workshop skill."

A friend of mine, a well-known employer of labour both in England and Russia, whilst recently conversing on this topic with me, remarked: "The Russian would, long ere this, have proved himself a formidable competitor with the foreigner, had his practical attainments been on a level with his theory; but although he could, on paper, easily build you a bridge, dock, railway, or steel works, and mathematically demonstrate how a thing should be done, and what ought to happen when it was done; yet, unfortunately, he could not do it himself, and would often spend hours among his treatises seeking the solution of a working difficulty, which the file and screw-key expert would instinctively grasp at, and instantly remove."

This was a state of things that could not exist for ever. Even the most oblique edu-

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cational vision at length saw that a change was necessary. The successful example of Germany and America, however, proved that there could be no diminution of the scientific curriculum. It was plain to be seen, then, that the reform was to be effected by a stern realisation of the importance of increased manual skill—that the ability to construct, take to pieces, or drive an engine well, was just as necessary as the making of elaborate calculations concerning it.

The change in programme, therefore, was supplementary rather than eradicatory; the only alteration consisting in the abandonment of the notion that a knowledge of text-books was a substitute for that acquaintance with the working life of a machine that can only be obtained by living with it ten hours out of the twenty-four.

The "men from the institutes" have assimilated the facts thus forced upon them. They have again begun to pass their vacations in the various manufactories, where, abandoning the attitudes they formerly struck, and becoming more amenable to workshop discipline, their time is now spent with much greater profit; whilst they are gradually growing to consider their "technologue's" diploma as a simple stepping-stone to further requirements. Hence, this may explain why many of the mills in the "Russian Manchester"—in the neighbourhood of Moscow—are now under native supervision: a condition of affairs that is beginning to be imitated in St. Peterburg and other districts.

"Yes. Russia will have reached a more gratifying point of progress when the directive power of her industries is entirely her own, instead of—as has been the case in the past—largely imported. The endeavour to effect this makes a demand for highly trained workmen, to become one of whom is a patriotic duty."

Thus maintained Professor Mendeleef, the distinguished Russian chemist, as he, Bieleloupsky, Professor of Applied Mechanics in St. Petersburg, and myself, sat together, one day last year, discussing the past, present, and future of technical education in the Empire. There can be no question about the demand for skilled labour; a demand which, becoming recently much intensified by the extension of her railway system, the opening up of Siberia, and general development of Russia, has caused the Imperial authorities to promise ample financial aid to the work of technical education.

In response to this demand, too, the applications for places at the institute have been greater than could be satisfied, and have recently led to the erection of extension buildings at a cost of £100,000, to say nothing of the expenditure of £300,000 on a Polytechnic—in the curriculum of which commercial subjects will also find a place.

Thus far, then, this phase of Russian technical education has assumed a fairly satisfactory aspect. The sending abroad of her investigators has furthermore produced in the Empire a little of that American spirit which is never content with well, but always strives to go one better.

"Why should your foremen and managers alone have brains? Are they the only men, the cultivation of whose intellect is likely to be of service to your nation? Depend upon it, you will have only half-solved the problem you are grappling with until you have raised the mental standard of your workmen all round."

Such advice, given to the Muscovite who happened to seek foreign opinion, not only coincided with the views of many Russians who took advanced ground on education in general, but also found favour among others who have always contended, and not without reason, that it might be advisable to adopt some variation from the usual plan of turning out fully-fledged foremen and managers from the technological institutes. They have urged that the better scheme is to increase the ordinary workman's intelligence, and from the best of the workmen to obtain the foremen; letting the most efficient of the latter acquire the manager's position.

The Commission which was, ultimately, in St. Petersburg, appointed to deal with the question of enlarging the then existing scheme of technical education, consisted of school directors, merchants, manufacturers, and one or two others specially qualified; the result of its labours being the establishment in the capital of a lower grade technical school, whilst thirty more institutions of a similar kind either have been, or are about to be, erected at Nijni Novgorod, Perm, Baku, and other places throughout the Empire.

"Our aim," said one of the commissioners, in explaining the recent development to me, "has been to give material form to an expression frequently heard in England, a few years ago, during a certain controversy on technical education — the bringing of the school to the workshop."

"We desire that the time a student spends here should be auxiliary to, but not a substitute for, workshop training" was the emphatically delivered remark of M. Yaurieff, the director, as he accompanied me on a tour of inspection through the newly-erected building in the Spaski district.

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This school, built at a cost of something like £20,000, specialises in the preparation of youths for employment, as ordinary hands, in places where chemistry enters largely into manufacturing processes. Other industries are recognised at other schools; for instance, at Perm the curriculum is framed with special reference to mechanical engineering and mining.

The students—sons of village moujiks, small shopkeepers, and urban workmen—are drawn from the country "two classes," and "*gorodskoe*" or town schools. The entrance age is 14; that of leaving, 17. Consequently, the pupils, at the close of their scholastic career, are still young enough to serve an apprenticeship to a trade: an apprenticeship which, built on three years' sound training in theoretical and applied science, ought to produce a superior type of artisan.

Lecture tuition, and demonstration in physics, ranges over the ground covered by, say, a recent edition of any of the text-books for the use of students in Stage II. (Board of Education); whilst, from a reference museum, microscopes, photo-micrographic outfits, apparatus for determining the flashing point of oils, hardness of cements, etc., can be obtained, for special work under the direction of a teacher. Time did not allow of my putting these youths through a test of their knowledge. I can only say, therefore, that every experiment witnessed in the classroom has to be repeated in the physical laboratory by the student himself, who is also encouraged to deepen his knowledge by, as far as he can, imitating the construction of apparatus he has handled. It is considered not sufficient that the working of, and scientific principles embodied in, a Sprengel pump, a box of resistance coils, or a Crookes radiometer, should be explained to a student; but a premium is put on his being able to make these things for himself.

The General Chemistry laboratories are arranged and equipped somewhat after the manner of those to be met with in a well-organised English science school. They have, however, this distinguishing feature: That whilst the instruction in qualitative analysis is general, in quantitative it takes a special form, that enables a boy during the whole of his school course to keep more or less in touch with the employment which he is subsequently to follow. For instance, there are submitted to him, for analysis, alloys from some foundry: soaps and fats from candle- or soap-making establishments: samples of oil from refineries: pottery ingredients: mineral colours, from a paint works; or perhaps a liquor used by a dyer, or calico printer.

The working complexion of his studies is further heightened by the task set in the technological laboratories, where a youth applies his theoretical knowledge by divesting himself of his coat, turning up his shirt-sleeves, and either making the gas and soap used in the school, tending a soda furnace, looking after a pottery plant, fabric bleaching, or working away at the production of iron and steel.

In addition to this thorough grounding in general and applied chemistry, the first year student spends eighteen hours a week going through an equally severe mechanical workshop programme. He takes his turn at driving the school steam engine, or his place at one of the half-a-dozen fires in the smithy: learns to make slots, bore, cut threads, file straight; and fits every tool he uses, as well as executes drawings of every machine in the place. The value of all drawings turned out by these students is enhanced by the novel fact that they are made, not from the flat copy, but from machinery and plant in actual use. They are characterised by accuracy, clearness, and artistic finish: have proved an instructive lesson to many English schoolboys to whom they have been exhibited; and by illustrating how much has been accomplished by the grandsons of serfs, have incited the more fortunate Briton with an educational stimulant that should prove beneficial.

Features equally as favourable as those mentioned in connection with this particular school (which I have only taken as a type) are to be observed in the rest of the lower grade schools of the country; and the remarks of one of the Imperial Commissioners, when speaking of certain contemplated schools for youths intending to follow a textile trade, are worthy of notice:—

"It is vain to expect the Russian moujik, with his past traditions, to toe the same line of excellence as the German—cradled 'mid an educational environment: the go-ahead American; or the Briton—heir of the industrial ages. It is better, therefore, to frankly recognise this, and apply our force at a more effective point. As we cannot obtain the desired result from the old order of things, we will see what can be done with an entirely new one; and by giving the son advantages his father never possessed, hope for an improvement in our position."

In England, the hardship entailed upon a labouring man by keeping his son at school until he is sixteen or seventeen would be greater than in Russia, where the minimum

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age for factory employment is higher, and there is no "half-timer" trouble to contend with. This removes one difficulty that otherwise would attend the projected experiment, and the decided readiness with which many thinking Muscovite workmen have fallen in with the scheme bears encouraging testimony in favour of its possibilities.

It is true that the effect of his three years training in a lower grade school will not be evident immediately upon a youth entering a weaving alley, mule gate or cardroom ; but there can be no question that, other things being equal, he will have developed into the finer mill hand by the time he is twenty-one ; for it must be borne in mind that he is still young enough to learn his trade.

It seems only reasonable to expect that a youth who has been taught the construction of a textile machine, and can recognise the mechanical principles involved in it, and the physical phenomena manifested during its working, will take more interest in his trade than if he were deficient in such knowledge ; and if he takes an interest in his work he will do it better.

The popular notion of a textile operative and his work being simply one machine minding another requires combatting ; for, in spite of the fact that modern improvements have considerably increased the output of, say, a spinning mule, besides causing it to perform many duties at one time done by hand : yet, at no period in the history of the cotton trade has there existed greater need for intelligence on the part of the operative spinner. The duties of an overlooker are clearly defined. In certain well-understood cases no one else may use a screw-key. But there are scores of details, attention to which will produce less breakage, and a bigger yield per spindle ; whilst their neglect entails a greater amount of thread piecing, and a more frequent demand for the services of the overseer. The latter is generally best pleased with the hand requiring his services least : because then it is clear that yarn is being turned off in a more satisfactory manner. Skill in the prevention of breakdowns is one of a man's greatest recommendations to a master ; the ability to cause "good spinning" further enhancing his reputation, for a thread that is full of piecings is not of such quality as one without them. It frequently happens that the more intelligent of two operatives will, from a somewhat lower grade of cotton, make as "good spinning," as his fellow using a higher grade : or will, as it were, entice 5 per cent. more work out of a machine, without changing its speedwheels ; or, should he be a designer with a knowledge of loom building and ability to weave, he will save such needless labour as would be caused through impracticable designs.

Therefore, one can readily understand an employer's desire for increased intelligence on the part of his employees, seeing the advantages accruing from it in modern competition, where success is often based on microscopic margins. Hitherto, the Muscovite workman has been mainly an imitator, in which capacity he is almost unsurpassable. But, for the industrial excellence of a nation, fertility of ideas, as well as reproductive skill, is requisite – the power to create as well as creditably execute ; since manufacturing pre-eminence demands either better work without increased cost, cheaper work with no diminution of quality, or work which, although only of a usual standard as to price and quality, may yet possess the feature of novelty. To effect this, inventiveness must come to the aid of automaton-like dexterity, and it is only natural to expect that, in the future, —owing to the amount of trained practical intelligence brought into play by the establishing of these lower grade schools, evening science class attendance (a feature which Prof. Mendeleef tells me they are trying to encourage also in Russia), and alteration in the ideals of the "men from the institutes"—this inventiveness will not be lacking, but will result in either the birth of new methods, or the improvement of old ones in connection with the working details of Russian industries. In conclusion, I might state that General Golovin has recently supplied me with a few figures that are interesting. They show that the total number of students at the St. Petersburg Technological Institute is 1,207, made up of 1,038 in the mechanical department, and 169 in the chemical. During the last ten years, 10,000 students have passed through the Institute. There are over 700 students at Kharkov ; about 1,000 at Moscow ; 600 at the Mining Institute at St. Petersburg ; at the Institute of Ways and Communications, 885 ; at the Institute of Architects, 316 ; Electrotechnical, 196 ; Riga Polytechnic, 1,500 ; Warsaw, 459 ; Kiev, 195 ; to say nothing of the students in attendance at the new Institute at Tomsk, the School for the Ways and Communications Branch of Civil Engineering at Moscow, and the new Mining School at Ekaterinoslav. A new Polytechnic is also to be opened in St. Petersburg, which is to cost 5,000,000 roubles.

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THE FIBROUS CONSTITUENTS OF PAPER.

LINEN—(*continued*).

By CLAYTON BEADLE.

Photo-micrographs by John Christie, F.R.M.S.

IN order to appreciate the position which linen occupies in relation to the various fibrous materials used in the manufacture of paper, it is necessary to adopt some classification from a paper-maker's standpoint. I am disposed to think that the most suitable classification is that of Monsieur Marcel Rostaing, which is as follows:—

Class 1. Cotton, linen, hemp.
" 2. Straw, esparto, bamboo.
" 3. The chemical woods.
" 4. The mechanical woods.

This is based on what Rostaing describes as the "cellular injection." The lignine which binds together many fibres and fibre bundles is regarded by Rostaing and others as a compound of vasculose, cutose and pectose. As the plant advances in age this material becomes harder and harder in order to form the wood, and penetrates more into the cellular walls. Hence the expression, "cellular injection." During boiling under pressure with "bisulphite" or caustic soda, the cutose and vasculose are dissolved; the pectose is changed, during the retting process, into soluble pectic acid. This process cannot be carried with some fibres to the extreme limits of the removal of the lignine or its constituents, without in some measure acting upon and rendering soluble the cellulose. Rostaing draws a simile between the action of rust in oxidising iron, and the action of the lignine in contact with the air in oxidising and converting cellulose into hydrocellulose; which last-mentioned compound is in a large measure soluble in solutions of caustic soda with the formation of substances of the nature of pectic acid. There is strong evidence to show that pectose substances, lignine as well as resins, act as bearers of oxygen to the fibre, and so by their presence bring about its disintegration and destruction. This subject will be considered more in detail in reference to mechanical wood. The theory affords an explanation of the rapid deterioration of paper made from mechanical wood (which contains, of course, all the original constituents of wood), and the superiority of annual plants as raw materials for paper-making. This view, I believe, is not considered as justified by recent researches: Mr. C. F. Cross, who has paid much attention to this subject, is disposed to regard it as untenable. I have not studied this branch of the subject very closely, but I am inclined to favour the views of Fremey, Rostaing, and others.

There are several other classifications of paper-making fibres with more scientific, but perhaps less practical basis. In a recent publication I have drawn attention to the different modes of classification in accordance with lignification, length of fibre, durability, etc. These different classifications, when taken together,

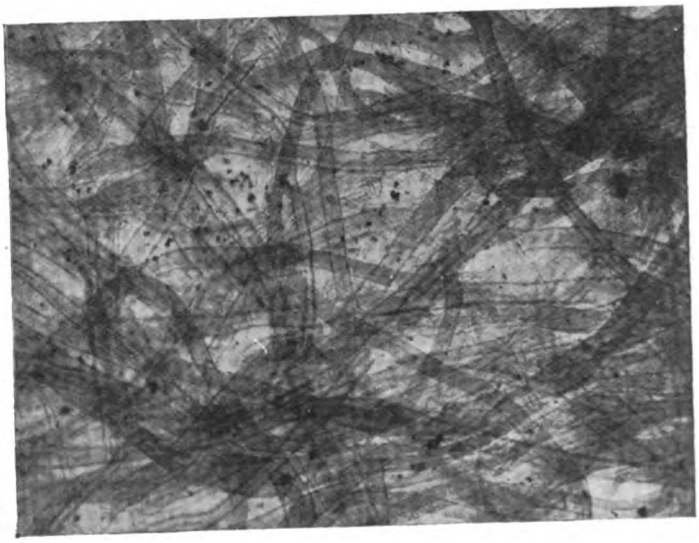

FIG. 1.—SPLIT SECTION OF HAND-MADE PAPER.
Direction of small laid lines indicated by arrow.
(*Magnification, 110 diameters.*)

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FIG. 2.—FIBROUS ELEMENTS OF PAPER, AS SHOWN IN FIG. 1, CONSISTING OF HEMP, COTTON AND FLAX.
(*Magnification*, 110 *diameters*.)

afford some sort of practical estimate of relative values.

The subject of water-marking, and the laid and wove marks that appear in a paper when the same is held up to the light, become more interesting when studied by means of the microscope. When papers are tested for strength it may appear somewhat strange that the fracture does not more often take place along the water-mark or chain-marks, because when the paper is looked "at" or when it is looked "through" these appear much thinner than the body of the paper. Why is it that the paper does not break along the thin lines or marks? I was somewhat puzzled to account for this, but the reason of it now appears to be obvious.

Fig. 1 shows the arrangement of fibres in a hand-made paper; the arrow indicates the direction of the small laid lines. The lighter portions are believed to correspond with these lines, but the left-hand bottom corner of the figure is dark, probably due to the section being very much thicker at this point: the irregularity of "split" section, which frequently appears, serves to obscure the point at issue. This photograph, although by no means directly, led me to suppose that the laid lines pushed aside those fibres in their immediate neighbourhood that were parallel to the lines or nearly so; whereas those fibres that made a greater angle than 45° with the laid lines were left undisturbed. This point, however, required more careful investigation. Fig. 3 shows the arrangement of fibres in a cigarette paper, the direction of the two arrows indicating where the two laid lines appear. The centre of the figure, appearing darker than the rest, is the space between the laid lines which, of course would appear darker if the paper were held up to the light. It will be noticed that the background, *i.e.*, those fibres furthest away, appear to be arranged more or less in different directions, whereas those fibres in the foreground in the centre of the figure are arranged mostly in the direction of the laid lines. It is obvious that in order to determine the effect of the water-marking on the rearrangement of the fibres, it is necessary to split a section from off the surface of that side of the paper on which the water-mark has been produced, as the fibres on the other side are not disturbed by the water-marking. If a "laid" paper is placed upon a table with something at the back of it, such as blotting paper, and with the laid marks uppermost and viewed in a good light at different angles, it

FIG. 3.—SPLIT SECTION OF CIGARETTE PAPER, SHOWING ARRANGEMENT OF FIBRES DUE TO WATER-MARK.
Direction of small laid lines indicated by arrow.
(*Magnification*, 100 *diameters*.)

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will be seen that the paper presents the general appearance of a ploughed field, and that the fibres on the furrows run in one direction.

Let us assume that we are testing a strip of laid paper with the thin chain marks running across the slip and, of course, at right angles to the direction of pull. As the strength of a paper of given materials, made under given conditions, varies with its thickness, under ordinary conditions the paper would invariably give way along the thinnest section, *i.e.*, the chain mark. This seldom happens, the reason being that when this thin mark is at right angles to the pull, the fibres of which the thin mark is composed (those which give the paper strength in this particular direction) are pointing in the direction of the pull. Assume another case, in which the thin chain-lines are in the direction of the pull: the wires which produce these thin laid marks displace their own volume of fibres, and the fibres so displaced are parallel to the marks. The net result appears to be that the paper is not affected in strength in either "machine" or "cross" direction by the wire marks. This holds good so long as the pull is at right angles to the thin marks, as it is in laid marks when testing in machine and cross directions; but it sometimes happens that in testing a paper both in the "machine" and "cross" direction the water-marks are at an angle of 45°, as in the case of a big W, when the strokes extend the whole width of strip to be tested; in such cases the break often takes place along the stroke of the letter, where the fibres are taken at a weak and unguarded angle. The "appearance" of a water-mark may be due not only to the differences in *thickness*, but also in the *direction* of the fibres which constitute the water-mark and body of the paper.

Although as a general rule the strength of machine-made papers varies considerably when tested in one uniform direction at different parts of the same web, occasionally one finds paper showing wonderful regularity. Thus in one instance I found a uniform test of 15·2 lb. breaking strain when tested five times in the cross direction. The stretch in this direction was almost as regular. In the machine direction the strength varied between 21·4 and 21·0, and the stretch was 3·2 per cent. in each case. But this is the most regular test out of the many hundreds that I have made. It appears that when there is great regularity in one direction, there is also in the perpendicular direction; but that the strengths in these two directions may be very different from each other, as in the case above cited. It is interesting to note furthermore that laid papers are at least as regular as wove papers in respect of individual tests in any particular direction.

For the purposes of this article I have endeavoured to obtain machine and hand-made papers consisting entirely of linen fibres. This was a matter of extreme difficulty. The only instances that I know of (if we except the Bank of England notes) guaranteed all linen, are for drawing papers used by many of the leading artists in this country. The linen is specially prepared in a way that is calculated to ensure the greatest amount of regularity and durability. These papers are hard-sized with gelatine, which, of course, gives them greatly increased strength. It is extremely difficult to obtain hand-made paper in which the strength is equal in all directions; but I was led to believe from the split sections of the above-mentioned paper, which show a fairly regular distribution of fibres in all directions, that the paper would show considerable uniformity in strength.

In order to arrive at this, I made use of what I call the "fan method" of testing paper. Take a hand-made paper and hold it up to the light so that you read the water-mark the right way round. Hang it vertically downwards so that the letters are exactly horizontal. Hold a fan at the right-hand bottom corner in a line with the vertical edge (or the "A" direction); let it open so that the horizontal edge corresponds with the bottom of the sheet ("B" direction). Assume that there are ten sections of equal angles, one commencing at 0° and the other ending at 90°. This will represent the manner that the paper is marked out for the purpose of cutting the strips. This gives us tests every 10 degrees. If it is desired to take the other angles, *viz.*, from 90° to 180°, we will assume that the fan is placed along the left-hand vertical edge and allowed to open towards the right. This is the plan which has to be adopted when the sheets are not large enough to allow of all the angles being tested. When the sheets are very large, assume that the fan is placed vertically upwards and equidistant from the two vertical edges, and allowed to open right and left. The advantages of doing the whole of the tests on one sheet are obvious when the individual sheets show considerable variation. I have now made a large number of tests from 0° to 180°, and in some cases every 5 degrees.

Fig. 4 shows the results obtained with the above hand-made linen drawing paper. The stretch was also determined. The stretch determines the amount of elongation, calculated

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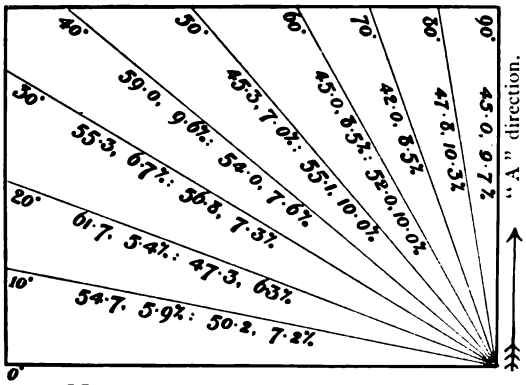

FIG. 4.—SHOWING THE BREAKING STRESS, IN LBS., AND PERCENTAGE STRETCH OF PURE LINEN HAND-MADE PAPER WHEN TESTED AT DIFFERENT ANGLES.

(*This is one of the few papers nearly equal in strength in all directions and in all parts of sheet.*)

TABLE I.

Same paper as in Fig. 4, but tested in the ordinary way.

Cut in direction A.		Cut in direction B.	
Breaking Stress, in lbs.	Stretch.	Breaking Stress, in lbs.	Stretch.
63·0	5·2%	54 9	12·8%
46·7	7·0%	57·5	12 0%
57·1	6·5%	56·8	12·0%
48·4	8·2%	57·9	12·0%
60·8	1·0%	*48·0	9·5%
Mean 55·24	5·58	55·02	11·66%

Thickness of strips = 0·11 mm.
Width ,, ,, = 25·00 mm.
Sectional area = 2·75 sq. mm.

as percentage on original length of strip taken for tensile strength. The strip is measured at the commencement of the test, and again just at the time of fracture.

Table I. shows the same paper when tested by the ordinary method, *viz.*, by taking five strips in the A direction, and five in the B direction, and calculating the mean of each. It will be noticed that the mean strengths in these directions are almost identical, but that the stretch is irregular in the A direction and fairly constant in the B direction. Furthermore, although the tensile strength is very uniform, the average figure for the stretch in the A direction is only about half that of the stretch in the B direction. This is also demonstrated in Fig. 4 at the different angles. This particular paper is the strongest that I have been able to obtain.

Table II. refers to a hand-made linen paper, very similar to the foregoing, but rather thicker; and although there is greater strength shown, when one comes to make allowance for the thickness it is found not to be so strong as that used for Fig. 4 and Table I.

The sizing qualities of some papers are affected by stretching. This can be exemplified by taking a strong, thin, well-sized linen bank and determining the tensile strength. When the strip is removed from the machine, that portion which was under the clamp, and consequently not submitted to strain, is still found to be hard-sized when ink is applied by means of a pen;

TABLE II.

Paper similar to that used in Fig. 4 and Table I., but thicker.

Cut in direction A.		Cut in direction B.	
Breaking Stress, in lbs.	Stretch.	Breaking Stress, in lbs.	Stretch.
60·3	1·8%	63·2	2·8%
54·1	3·8%	62·5	4·2%
54·3	3·2%	59·8	4·2%
57·2	1·0%	59·8	3·8%
Mean 56·48	2·45%	61·33	3·75%

Thickness of paper = 0·145 mm.
Sectional area = 3·425 sq. mm.

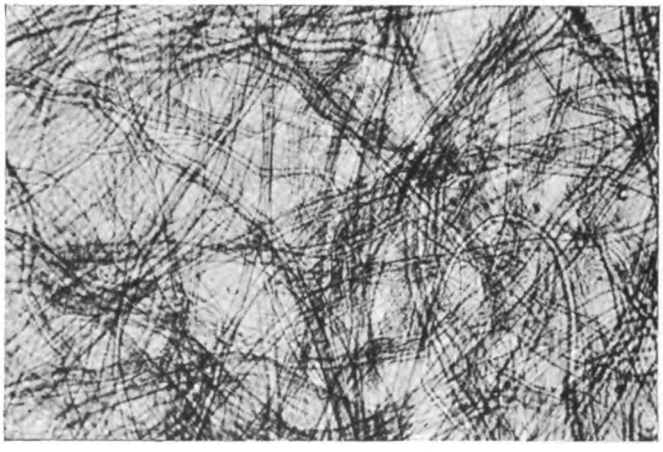

FIG. 5.—PURE LINEN DRAWING PAPER. SPLIT SECTION SHOWING EVEN DISTRIBUTION OF FIBRES.

(*Magnification, 90 diameters.*)

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but that portion which has been submitted to strain, although it may show no outward evidence of it, is often found to allow the ink to penetrate readily through the pores. The reason is that the paper has become elongated, and the microscopic fibres of gelatine, which ordinarily resist penetration of the ink, have been broken up and dislodged.

Turn again to linen drawing papers, Fig. 4 and Table I. This paper was found on analysis to contain 10% of gelatine. This is nearly double the amount ordinarily used for "hand sizing." Partly in consequence of this the paper is so strong that it behaves differently to ordinary papers when tested; about a second before the rupture takes place a noise is heard that appears to proceed from all parts of the strip. The noise is due, undoubtedly, to the various fibres being drawn away from each other: the paper being so uniform in texture, appears to be undecided as to where the point of rupture shall occur. After the paper breaks, it creeps up into corrugations and puckers. This is not noticed with ordinary papers, and is only to be noticed with very strong papers with great length of fibre. In fact, I think that it is peculiar to the linen fibre, as I have not noticed it even with very strong manilla papers. This puckering-up disappears slowly. It is due, I believe, to the individual fibres pointing in the direction of the strip being pulled out of their relative positions, whereas those that are at right angles to the strip are not affected in the same way. The ultimate fibres being very much strained, and possibly considerably elongated by the strain, crawl back immediately the force is released, occasioning waves or puckers at right angles to the direction of the pull. That these puckers, in some measure, ultimately disappear may be due to the fibres crawling back into the positions they occupied before the force was applied. The ultimate fibres are stretched only within the limits of their elasticity, whereas the paper as a whole is elongated by the slipping away of the fibres. The noise heard just before the fracture, is due, of course, to the fibres slipping away from their original positions. Tables I. and II. show that the stretch is occasionally abnormally low. This I believe to be due to filaments of fibres running perhaps the whole length of the strip, and preventing the natural elongation of paper from taking place.

FIG. 6.—SECTION OF PURE LINEN DRAWING PAPER AT RIGHT ANGLES TO SURFACE.
(*Magnification, 60 diameters.*)

If we calculate the strength of the above-mentioned paper in the manner we used for the paper in the article on Cotton, we shall find that the paper has a very much greater strength. We there found that the cellulose composing the cell wall of the cotton fibre is ruptured when a force is applied equal to about 31,000 grms. per sq. mm. of sectional area. The sectional area of strips broken in the case of Fig. 4 and Table I. is 2·75 sq. mm. Converting lbs. into grms. our linen paper of the above-mentioned sectional area breaks with 24,974 grms. pull. This is equal to 9,081 grms. per sq. mm.

We may assume that this paper contains about 50% by volume of air space. The breaking strain for fibre substance is, therefore, about 18,000 grms. per sq. mm. when the air space is eliminated. The force necessary to draw the fibres apart and so bring about the rupture of the paper is about 60% of the force necessary to rupture the

FIG. 7.—SECTION OF PURE LINEN DRAWING PAPER AT RIGHT ANGLES TO SURFACE.
(*Magnification, 210 diameters.*)

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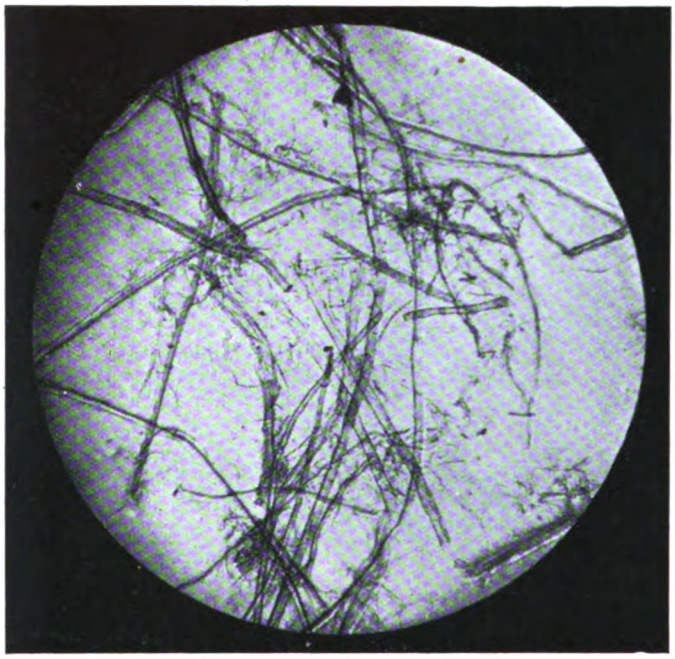

FIG. 8.—FIBROUS ELEMENTS OF PURE LINEN DRAWING PAPER.
(*Magnification, 68 diameters.*)

cell wall of the fibre. If by any means it should be possible to increase the felting properties of the linen or cotton fibre so as to double the above-mentioned tenacity, the ultimate fibres themselves would be broken asunder, and the paper, instead of tearing with a fibrous edge, would have a tendency to tear or rend asunder like a piece of metal. Fig. 6 is a photo-micrograph of a section of a very thick hand-made linen drawing paper, double elephant, 325 lbs., measuring about $\frac{1}{2}$ mm. in thickness. This paper shows evidence of very large air spaces; the result, probably, of the paper being so very thick. It stands to reason that a very thick paper would show a large amount of air spaces. Fig. 7 is a small portion of Fig. 6, under higher magnification, which may be recognised by the reader on the right-hand top edge. The appearance of this section is very different from that of sections of cotton papers or papers containing linen with a preponderance of cotton. The linen paper section under high magnification has the appearance of a mass of matted, entangled string. It is not surprising that the fibres are so firmly and stubbornly felted together, resulting in a very strong paper when well sized with gelatine. I have chosen for the purpose of illustration the linen fibre prepared in such a manner as to retain its characteristics; but in most papers where linen is used the fibre is derived from much-worn rags, and the characteristics are in a large measure obliterated, and less easily distinguished.

The individual unravelled linen fibres, as they appear in the beaten stuff, are shown in Fig. 8.

Dr. Paul Klemm, of Leipzig, a well-known expert in paper-testing, devoted most careful attention to criticising the C.B.S. units. He points out that the authors had not taken into consideration the effects of sizing materials in their calculations of volume percentages. At the time this publication was issued we had not determined the factor for commercial gelatines as used for sizing papers. The following work was undertaken with this object, and shows that the specific gravity of different grades of gelatine is very constant, considering the great differences to be found in its other physical qualities. The figure ranges between 1·34 and 1·40.

Weight of 250 cc flask		70·6
Weight of 250 cc flask, plus petroleum		245·2
Weight of 250 cc flask, plus water		320·8
Therefore weight of water		250·2
Therefore weight of petroleum		174·6
Therefore specific gravity of petroleum		·6979
For practical purposes may be taken as		·7
No. 1.	Weight of gelatine in air	4·35
	Weight of gelatine in petroleum	2·07
No. 2.	Weight of gelatine in air	17·41
	Weight of gelatine in petroleum	8·26
No. 3.	Weight of gelatine in air	29·63
	Weight of gelatine in petroleum	14·18
No. 4.	Weight of gelatine in air	18·62
	Weight of gelatine in petroleum	8·89
No. 5.	Weight of gelatine in air	20·68
	Weight of gelatine in petroleum	9·86

RESULTS.

No. 1	1·336	Sp. gr. of air-dry sheets.	
No. 2	1·409	,,	,,
No. 3	1·343	,,	,,
No. 4	1·339	,,	,,
No. 5	1·338	,,	,,

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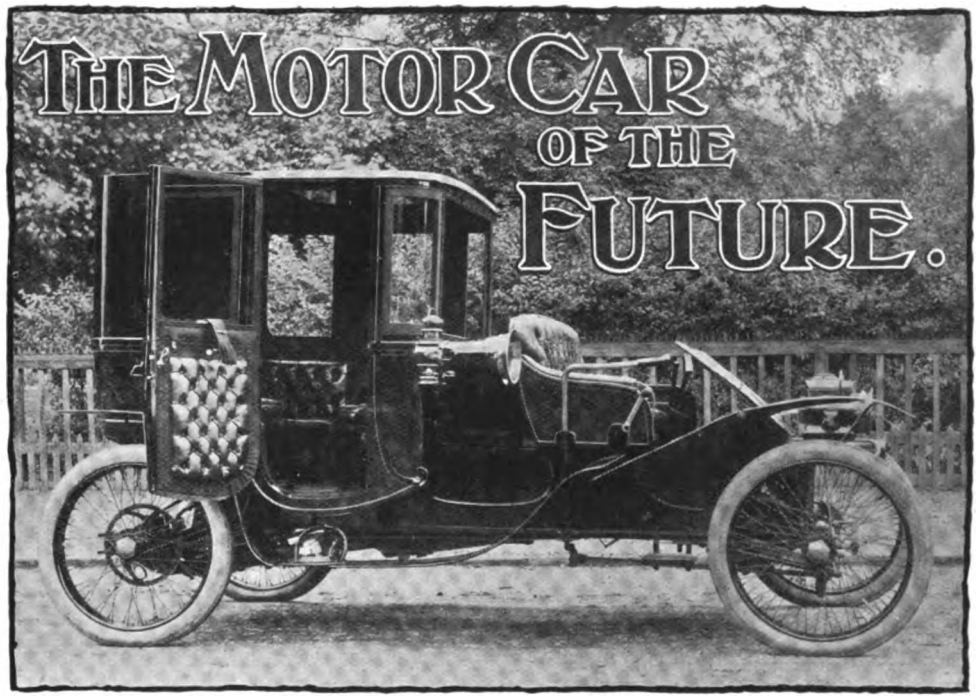

By F. W. LANCHESTER.

PART II.—THE CAR CONSIDERED AS A ROAD VEHICLE.

WHEN we pass from the motive power aspect of the car, to consider the car from the point of view of a road vehicle, our attention is brought to bear on an entirely new set of problems.

The following is an analysis of the requirements or desiderata of a car considered functionally as a vehicle :—

Steering.—Steering by front wheels carrying not less than 25% of the total weight.

Driving.—Driving or propulsion by rear wheels carrying not less than 60% of the total weight.

Wheel Base and Gauge.—Of sufficient proportion with reference to the height of centre of gravity to render absolutely safe from capsize, both longitudinally and transversely. The length of wheel base must also be sufficient to provide adequate access to the carriage body and ensure "easy running." The gauge must also be sufficient to allow for the suspension motions of the body, and permit of a sufficient angle of lock to the steering wheels.

Suspension.—The suspension must support as large a proportion as possible of the weight of the car; all unsuspended weight is a detriment to speed and durability. Elastic tyres (india-rubber or pneumatic) may be considered as accessory to the suspension, in the present sense. The suspension must be sufficiently elastic, the elasticity being measured by the oscillation period of the carriage body under normal load.

Handling Gear.—The handling gear (sometimes termed driving gear) must be dynamically correct—that is, the fact must be taken into account that changes of motion impressed on the car react on the handling gear, and render the problem different from what it would be if the car were fixed as a stationary engine.

I SHALL take the above sub-headings seriatim, and enquire to what extent the conditions are complied with in existing cars, and what further improvement is possible or may be expected.

Steering.—The present system of steering with the wheel axles pivotted on separate heads, and coupled on what is known as the Ackerman system, is entirely satisfactory, and there is no reason to anticipate any great improvement or departure. The correct mounting gives the steering heads a rake forward of about three degrees; that is to say, the point of intersection of the pivot centre

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with the ground is in front of the line of contact of the wheels, and when so mounted the wheels will continue to track even though the coupling link is disconnected or severed. The arrangement of splayed arms connected with a direct coupling link does not give quite a true radial motion to the wheels, but if properly proportioned the error is not greater than the tyre can easily accommodate.

Driving and Propulsion.—We are not here concerned with the details of the driving mechanism; these have already been dealt with. The practice of driving through the rear wheels is now universal, and the only extent to which the commonly-adopted disposition is open to criticism is on the question of weight distribution; there is frequently a deficiency of weight on the driving wheels, due to the forward engine position. In cases where the front axle is carried well forward of the bonnet, this defect of "ballast" is not great; but where an endeavour has been made to shorten the wheel base by arranging the front axle far back under the engine, the objection is serious.

Wheel Base and Gauge.—I consider that at the present time the generality of cars have their wheel gauge too narrow in proportion to the height of their centre of gravity. The same objection applied, in the early days, to the length of wheel base, but since about 1901 the length of wheel base employed by most makers of repute has been satisfactory. The question of length of wheel base is one of some complexity; outside the considerations of stability and smoothness of running, the problem is closely associated with questions of engine position, and carriage bodywork access; I am dealing with this problem under a separate heading later in my present article.

It has always been a mystery to me why so narrow and cramped a wheel gauge has been generally adopted. For some years several makers in America, and in this country the Lanchester Engine Company, have shown that a wide gauge has no practical disadvantage, and has several important points in its favour. These advantages in brief are—(*a*) perfect lateral stability (tested by capacity to slip sideways on dry road rather than overturn), (*b*) increased smoothness of running, owing to diminished angular displacement caused by obstacle of given dimension, (*c*) great diminution in dust raising, due to distance of tyre disturbance from whirlwind caused by car body, and (*d*) lower seating accommodation by arrangement of body between wheels instead of over them. An objection frequently urged against the wide gauge is the difficulty of passing other traffic; in my opinion this difficulty is more apparent than real. A car possessed of ample stability can utilise, in effect, two or three feet more road width in country districts than is safe for the narrow gauge machine; this more than compensates for the extra foot of wheel gauge

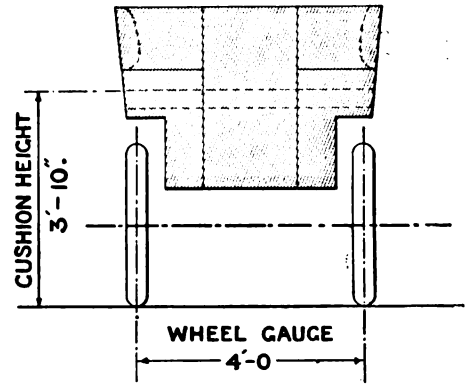

FIG. 11.—NARROW GAUGE CAR.

employed. It is true that this does not apply to town driving, and it is possible that here the narrow gauge has a slight advantage; but in practice I believe the advantage to be very small indeed.

The comparative proportions of narrow and wide gauge cars can be seen by reference to Figs. 11 and 12, from which it appears that the difference is more than one of degree. In Fig. 11, which shows approximately the proportions of a "Panhard," the

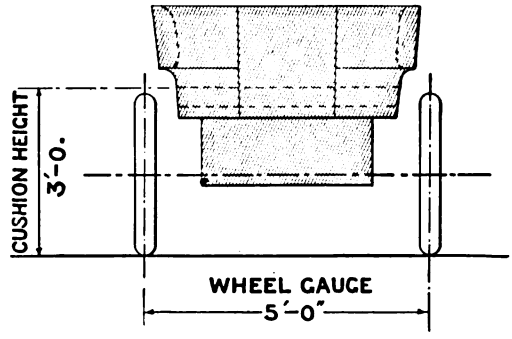

FIG. 12.—WIDE GAUGE CAR.

seats are raised above the wheels, which they overhang, not only giving the car a top-heavy appearance, but rendering it liable to "turn turtle" if recklessly driven. Fig. 12, on the other hand, shows the proportions adopted in the "Lanchester," where the seat plan is dropped between the road wheel, and the

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centre of gravity so lowered that the car will slide sideways rather than capsize, even on a dry road. The majority of makers have increased their gauge during the last year or two, and this is certainly a move in the right direction, although at present the Lanchester is the only car in which the wide gauge arrangement is fully developed.

I consider that the relation between the height of centre of gravity and wheel gauge is one of vital importance to the motorist. All high-speed cars should, in my opinion, be constructed so that they will, even on a dry road, slide *like a book on a table* rather than overturn. If such a test were compulsory, we should hear less of fatal motor car accidents than we do to-day; unfortunately, the low-built car lacks ostentation, and there are some who are prepared to pay for ostentation even with their necks. I think, however, common sense will eventually prevail, and the tendency from year to year will be to build lower and wider.

Suspension. — The form of suspension ordinarily used is a direct legacy from the horse-drawn vehicle; and, all things considered, it has undergone a remarkably small amount of alteration. Taking it all round, it has proved itself very well suited to its purpose, and there is no doubt that for certain classes of vehicle it would be difficult to suggest anything better. One of the weak points of the ordinary suspension is that the *side location* is high. By the *side location* I mean the point at which the car body is attached to the under-frames, by which the two are located relatively to one another laterally. The result of this being high above the ground is, that all unevenness in the road tends to give the body of the car a side oscillation, which the springs are unable to take up; this results not only in giving great discomfort to the passengers, but also the reaction of this side throw comes on to the tyres and results in their rapid destruction. This is really the only real reason why wood wheels are advantageous; a wood or artillery wheel will "spring" about two inches at its rim, and thus assists the suspension by yielding in the direction in which the latter is rigid. The only suspension arrangement which constitutes any radical advance on the customary type is that used in the "Lanchester," whose extreme flexibility can be judged from Fig. 13, where it is shown surmounting a two-foot obstacle. The most important point about this suspension is the low side location, which is brought within eight or ten inches of the ground line, thereby practically getting rid of the "side throw" and its reaction on the tyres, and permitting of a rigid form of wheel being employed.

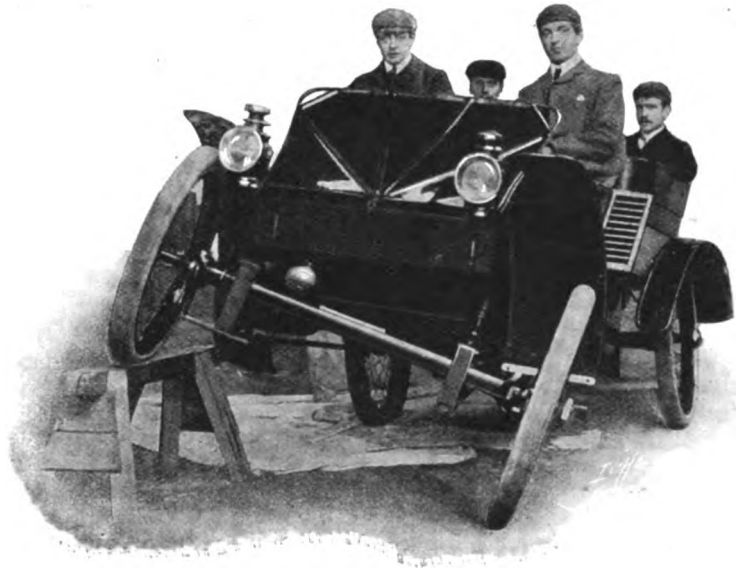

FIG. 13.—TO ILLUSTRATE THE FLEXIBILITY OF THE "LANCHESTER" SUSPENSION.

One important point connected with the suspension, which is at present sometimes overlooked, is the fact that the "weaker" the springs are, the greater is the weight of steel that must be put into them. I use the term "weaker" here in the popular sense to denote the reverse of "stiff"; it is, of

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course, inaccurate. The spring performs its function by the storage of energy: and the less stiff, or "easier" it is made, the greater its deflection under load and the greater the energy it must store; now one pound of spring steel will only store, with safety, a certain amount of energy—about 6 ft.-lbs. in fact—and consequently one cannot obtain easy running without putting plenty of metal into the springs. The actual amount necessary depends on, and is proportional to, the suspended weight of the loaded car; and this proportion should certainly not be less than about 6 per cent.

The most scientific criterion of the stiffness of the suspension is its oscillation period. This "period" can be calculated, and the car designed to give whatever "period" is deemed desirable; it can also be determined approximately by experiment, the car being occupied by passengers all standing, who by repeated slight movements of the knee (like an unfinished jump) keep the suspension oscillating whilst an observer takes count. I have found that calculation and experiment agree fairly closely, though a 10 per cent. error may sometimes occur. The period which I have found most satisfactory is about ninety complete oscillations a minute; but as long as the number does not exceed one hundred the riding is fairly comfortable. Perhaps at some future date makers' catalogues will quote the period of their suspension, instead of taking refuge behind comparatively vague terms; but the public must first be educated.

I have for the present purpose mentioned tyres as being accessory to the suspension; this is only true with certain qualifications. Considered simply as a means of suspension, a pneumatic tyre has probably a "period" of the order of 400 or 500 a minute; it has, however, a peculiarity that is possessed by no other form of suspension: any small obstruction, stone or the like, is absorbed, or as the French put it, the pneumatic "*boit l'obstacle.*" The essence of this peculiarity is that the tyre does not simply *average* the surface with which it is in contact. It does more: to all intents and purposes it *takes no notice at all* of such small stones, etc., as it can *put out of sight*, and even larger ones are not assessed at their true value. I have always considered this advantage to be such as to render the pneumatic tyre absolutely essential for fast cars and bad roads; and it can be observed that, in spite of its admitted expense of first cost and maintenance, and the efforts that have been made to "push" solid rubber, the pneumatic to-day is practically universal.

Handling Gear.—As there are two systems of change gear, so at the present time there are two arrangements of handling mechanism: and in some respects, at any rate, the system of change gear goes hand-in-hand with the driving or handling mechanism.

In both the epicyclic and the intermeshing systems of change, the change gear itself is hand-operated; this may be regarded as necessary, owing to the much finer "touch" possessed by the hand than the foot. In the case of the epicyclic change, the hand operation completes the process; but in the intermeshing change the clutch withdraw requires to be operated at each change, in harmony with the hand motion: it is consequently an obvious necessity that the clutch withdraw should be foot-operated, and with the clutch withdraw, goes the brake actuation; for it is important that when the brake is required, two separate actions are not necessary. Hence we see that the arrangement of handling gear is largely a matter of logical necessity.

Beyond the above, each operating motion should be examined from the dynamic standpoint. As an illustration of this, I may take as an example a comparison between the old-fashioned "bath-chair" tiller and the side lever as used on the "Lanchester." The old "bath-chair" type was dynamically wrong; the motion of the handle was contrary to the direction of turning, and consequently there was a continual tendency to over-steer, owing to the action on the driver's body of the centrifugal force tending to exaggerate any steering motion made. The side lever of the "Lanchester," on the contrary, is moved in *the same direction* as the direction in which the car is turned, and consequently the effect of the change of motion on the driver's body is to moderate the steering effort and to render over-steering a physical impossibility, and this steering gear is dynamically right.

The same applies to brake mechanism; if applying the brake involves the movement of a lever forward it is dynamically wrong; this applies to most of the side lever brakes fitted. The correct arrangement of brake lever is one that is actuated by a backward motion, such as fitted to the "Lanchester," and which has recently been introduced by some of the leading makers on the French type of car.

It is of interest to point out that the tiller of a yacht is dynamically right, in spite of the fact that, apparently, it is moved in the reverse direction to that in which the boat is steered; this, though somewhat paradoxical, is explained when it is remembered that the helmsman stands aft, and the first effect of the

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steering effort is to throw the stern of the boat *in the same direction* as that in which the tiller is moved.

The ordinary steering wheel would be dynamically wrong if it depended for its actuation on a simple sideways motion imparted to the rearmost part of its rim; but this is not how it is actuated. The methods of different drivers vary somewhat, but in general most of the steering is done by wrist motion, or applying a *torque* to the wheel, rather than by a single pull or push. Considered as an application of torque alone, the steering wheel is all right.

In discussing the subject of handling mechanism in general, I think it unlikely that there is a great deal more to be learnt; I think that in future developments we may look for the continuance and extension of existing methods, and any change that does occur will probably be consequent on changes in the mechanism of the car itself.

The Wheel Base Problem.—It has been pointed out that the question of length of wheel base is one of some complexity. One of the most obvious developments of motor car design during the last few years has been the lengthening of the wheel base; the causes that have brought this about are twofold. In the first place, length of base tends to easy running and safety; short wheel base cars pitch badly on rough roads, and have been known to capsize backwards. In the second place, the requirements of access to bodywork, especially in side entrance cars, necessitates a considerable space between the front and rear wheels, which again means length of base.

The penalty of too long a wheel base is difficulty of manœuvring; a car to be handy in traffic should have a "turning circle" of not more than thirty feet. At the present time forty feet is more usual; there is, then, room for considerable improvement. The question of turning circle is not so important for a "touring car" as length of wheel base, as it is worth while putting up with some slight inconvenience occasionally, for the sake of the more luxurious running obtainable.

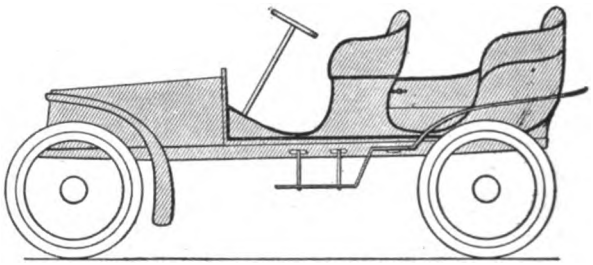

FIG. 15.—TO ILLUSTRATE CAR WITH SIDE ENTRANCE PARTLY OVER DRIVING WHEEL.

There is a very considerable difficulty in producing a car, otherwise satisfactory, in which sufficient space can be found for a convenient side entrance, such as obtains on horse-drawn vehicles, as broughams, victorias, etc. The difficulty is principally met, at the present time, by evasion. Some cars are fitted with a side entrance that is beyond reproach, but at the cost of a wheel base that stamps them at once as essentially touring machines (see photo reproduced at head of article); others are fitted with "trick" bodywork (Fig. 14), which is all right so far as it goes, but is only suited to particular types of open vehicle. Another arrangement is one in which the side entrance is arranged quite as much over as in front of the driving wheel (Fig. 15); this arrangement is very unsatisfactory, it penalises the diameter of the driving wheel, and at best necessitates a two-step climb over the mudguard.

It might be thought that the arrangements which are universally considered good enough in the matter of access in horse-drawn vehicles, would not be found much fault with in motor cars. No greater mistake could be made. Where do we find the motor car that requires to be climbed into like a dog-cart, or attacked like the box seat

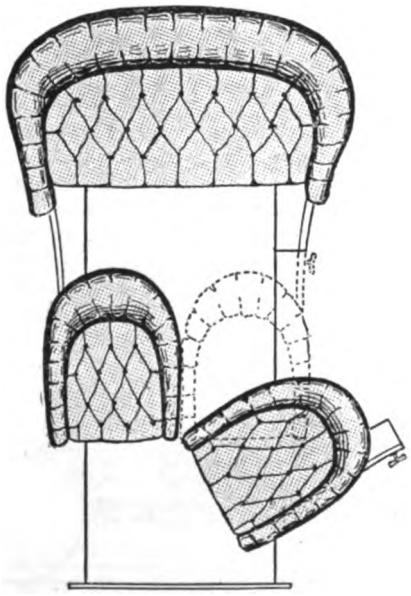

FIG. 14.—TO ILLUSTRATE "TRICK" BODYWORK.

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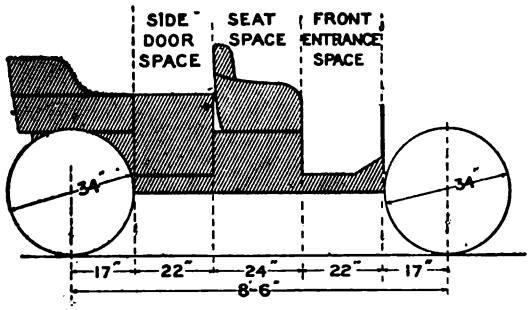

FIG. 16.—TO ILLUSTRATE THE CONDITIONS OF COMFORTABLE ACCESS AND SEATING ACCOMMODATION.

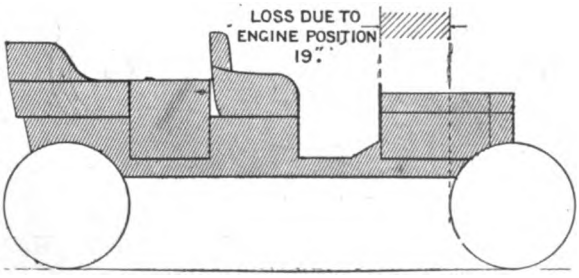

FIG. 17.—TO ILLUSTRATE LOSS DUE TO ENGINE POSITION, IN CAR OF ORDINARY PATTERN.

of a brougham, or one that has to be vaulted from like the back seat of a mail phaeton? Such arrangements do not exist at all; the buying public will not tolerate them.

We are in a position, then, to understand what we have described as the "wheel base problem." It obviously does not concern the two-seat car; neither does it apply to the specialised touring machine, where the wheel base may be lengthened to the extent required, without unfitting the car for its purpose; but it is the problem of the four-seat car for general purposes — the car for the suburban user, for the town doctor, and the motor car for street hire, etc.

Fig. 16 shows diagrammatically the necessary provision for comfortable access, and seating accommodation. It will be noticed that the doorways are figured 22 inches, and the seat space 24 inches; these dimensions are no more than sufficient for comfort. The wheel diameter has been assumed as 34 inches: this is common practice, and has shown itself about the right thing. The dimensions total 102 inches, or 8 feet 6 inches, and we may take this as the amount absolutely necessary to adequately meet the requirements of the public.

Now there is no fatal objection to an eight-foot-six wheel-base; and so long as this dimension is not seriously exceeded, it is possible to construct a car with a turning circle of under thirty feet and ample manœuvring capacity. The difficulty is, however, that with most of the existing arrangements of engine position, the wheel base is "cut to waste," so to speak—usually to the extent of one to two feet; this is shown clearly in Fig. 17, in which the loss due to engine position is figured in a typical car of ordinary pattern, and Fig. 18, which shows the corresponding loss in an 18-h.p. Lanchester. This additional length brings the wheel base up to 10 feet, which is well above the limit that is found desirable for anything but a touring machine.

At first sight nothing would be easier than to do away with the engine space loss, in the ordinary type, by allowing the motor to project further over the front axle, Fig. 19. It may be remarked, however, that this is not good practice, and the reason is not far to seek. One of the admitted defects of this type is that the weight of the engine is too much forward, and every effort must be made in the design to minimise this defect. Thus in a modern racer (Fig. 20) the motor is arranged more nearly central, and the driving seat thrown right out over the rear wheels. It is obvious at once that in a full-bodied car it is the bodywork requirements that force the motor forward, and reduce the "engine space loss" to the amount illustrated in Fig. 17; and any further pushing forward would develop a car with all the vices of being head-heavy, *i.e.*, hard to steer, and bad adhesion of driving wheels, with attendant danger of "side-slip." The central engine position of the Lanchester has been found remarkably advantageous in these respects; and there is no doubt that the subterfuge illustrated in Fig. 19 must be considered inadmissible. Either the weight of the

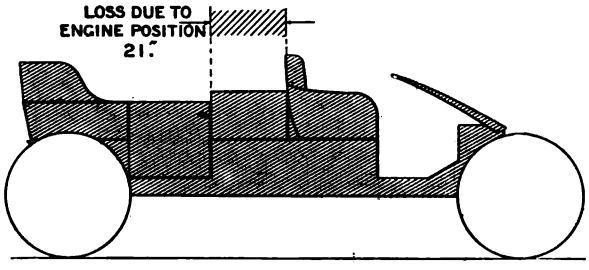

FIG. 18.—TO ILLUSTRATE LOSS DUE TO ENGINE POSITION IN THE "LANCHESTER" CAR.

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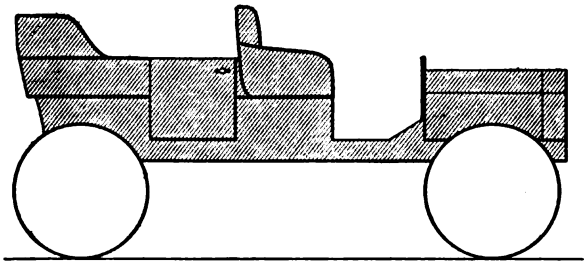

FIG. 19.—TO ILLUSTRATE CAR WITH ENGINE PROJECTING OVER THE FRONT AXLE.

engine must be reduced in the future, so that its position will become a matter of little moment, or the "out in front position" will become untenable.

It is difficult to say exactly what rearrangement would be possible to meet the somewhat exacting conditions of the problem. There are few makers who have been bold enough to attempt a solution; in fact, there are not many who are thoroughly aware of the fundamental nature of the difficulty.

The number of alternative positions is limited, and most of them have been explored in the past with only a moderate amount of success. The present Lanchester arrangement has no pretensions to constitute a solution; the Lanchester car was designed and is sold as a touring machine; and there are very few other types of car, amongst those that have been thoroughly tried, that constitute any departure from the ordinary.

The most promising avenue for the moment is to use every available means to minimise the inconvenience of the excessive length of wheel base, admitting it for the time being as a necessary evil. The greatest relief can be obtained by increasing as much as possible the "angle of lock,"—that is, the angle over which the steering wheels can range—and to thereby bring the diameter of the turning circle to within reasonable limits.

There appears to be no valid reason why, by a slight modification of the car frame, a 90 degree total angle of lock could not be obtained; that is, about 45 degrees on each "lock"; this would bring the turning circle of a car having an 8 feet 6 inches wheel base down to 28 feet diameter, and a car of even 10 feet base would not be altogether unhandy.

Such an arrangement of wide angle of lock was provided on an experimental Lanchester shown at the Richmond A.C. Exhibition in 1899 (Fig. 21); and though this arrangement is not directly applicable to a modern car, it serves as an illustration of what would meet the case.

In conclusion.—There is no doubt that, in addition to the direct influences at work, motor racing is still an important factor in the development of the motor car; and it is an influence that is not always beneficial. Racing undoubtedly makes a very great impression on the public mind, and there is a tendency, whether right or wrong, to copy the features of a successful racer to a prejudicial extent.

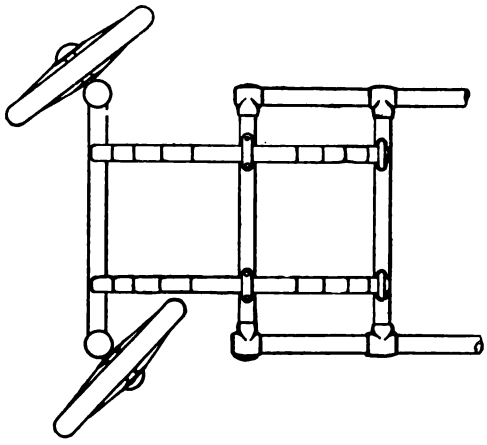

FIG. 21.—TO ILLUSTRATE WIDE ANGLE OF "LOCK."

I think that the time is approaching when cars for different classes of service will assert their individuality. It is true that the public has a tendency to jump at conclusions, and model ideals on one definite pattern; and there are always manufacturers ready to pander, hence the voiturette with enormous bonnet in front and a motor —somewhere else. I believe, however, that in the main the situation is governed by actual concrete advantages and disadvantages; that is to say, by considerations of engineering and common sense, though the lines of development may at times be somewhat indirect.

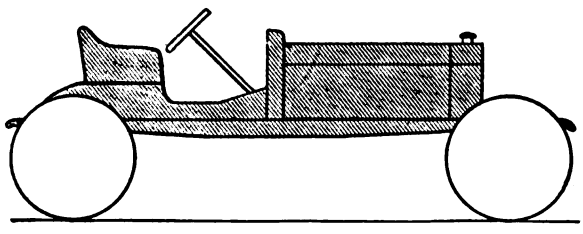

FIG. 20.—MODERN RACING CAR.

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POTTERY BODIES:
THEIR COMPOSITION AND PREPARATION.

By WILTON P. RIX, late Manager of Messrs. Doulton's Art Pottery, Lambeth.

THE compounding of pottery bodies from raw materials assumes a place of much importance in the manufacture, owing to the fact that the materials themselves are of complex composition.

The requisite elements which form these compound bodies are only ten in number, of which four are acids and six are bases. It is, however, seldom that any of these radicals are introduced in any uncombined form.

Thus it may be necessary that a certain body should contain 50 per cent. of silica, and of this proportion one-half only may be introduced in the form of ground flint or sand, the remainder being added in combination with other elements, as felspar, ball clay, or Cornish stone.

In most cases the physical condition of these elements, as well as their proportion, requires consideration, due regard being given to the purpose of manufacture.

Thus in an analysis, the total contents of silica may appear as 50 per cent. as stated above; but of that amount, it may be necessary that only 30 per cent. should be combined with other materials, the remainder being free from silica, which requires to be of crystalline texture to counteract shrinkage and hasten drying.

Were the proper condition of this portion of the silica neglected, and fine ground flint or fossil earth substituted for sand, the result, though showing the same analytical contents, would most likely fail to produce a body suitable for the class of goods to be manufactured.

It has been already stated that the elements used are very limited, and these can only be used within certain proportions. These limits are given in the following table, the body being free from water:—

	Highest Per Cent.	Lowest Per Cent.
Alumina	40	10
Silica	80	55
Lime	10 or occasionally 20	0
Magnesia	2	0
Alkalies	5 or occasionally 15 to 17	0
Oxide iron	8 or occasionally 20	0
Carbon dioxide	17	0
Sulphur trioxide	Small quantities which are to be avoided	0
Phosphoric acid	35 in soft porcelain only	0

In compounding a pottery body the operation may be approached from two entirely different standpoints.

First, it is possible to take a given natural deposit, and having ascertained its composition and properties, to decide what class of goods can be manufactured from it with the smallest addition of foreign materials, thus limiting the manufacture by the nature of the material. Examples of such methods are to be found in the manufacture of bricks, pipes and terra-cotta, etc.

Second, it is possible, before commencing to produce some given type of ware the composition of which has been previously ascertained, to bring together from other localities the various raw materials necessary, and subsequently to combine them in the requisite proportions. Examples of such wares are to be found in white earthenware, china and porcelain.

In the former case it is often usual to accept the physical condition of the material as it occurs; in the latter, the materials are all brought into a condition of uniformity, which has been found by experience to be most suited to the purpose of the manufacture.

Moisture.

In the statement of percentage of materials given above, the important element of water has been purposely omitted as being variable.

It is, however, quite necessary to take

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notice of this also, because the proportion of water most suitable for each body and each class of manufacture is confined within very narrow limits.

Very plastic bodies will absorb from the atmosphere a considerable amount of moisture —usually from 4 per cent. to 6 per cent., and this proportion of hygrometric water may be further increased to three times this amount, if iron oxide, organic substances, or some hydrates of silica, are added in considerable quantities.

Apart from this, however, further water is required to secure suitable consistency in forming the goods. Hence this is termed "water of formation," and is afterwards entirely evaporated by placing the ware in a perfectly dry atmosphere.

It has already been stated that the amount of water required depends on the kind of body to be treated; but it is also influenced by the class of ware to be formed, and the method of making. Thus bodies may be—

(*a*) *Liquid*, as in the making of cast or slipped ware.

(*b*) *Soft*, as in the making of mud bricks.

(*c*) *Plastic*, as in moulded earthenware.

(*d*) *Stiff plastic*, as in machine pressed plastic tiles.

(*e*) *Dry or dust*, as in dust-pressed wall tiles.

The quantity of water required for dust body is about 10 per cent. The amount required for *liquid* or *slip* body is from 20 per cent. to 30 per cent.

Adaptation of Body to Manufacture.

The composition of a fine pottery body from raw materials demands uniformity of the materials themselves. For this purpose it is usual to grind and manipulate these previously to bringing to the pottery. Thus—

Flints are calcined and ground either in water or dry.

Felspar and Cornish Stone are ground in water.

China Clay is washed out of the disintegrated granite rock by streams of water which are directed upon it, and the sedimental deposit of clay is partially evaporated in huge tanks or basins, being finally dried by artificial heat.

Ball Clay is dug out of the clay pits and

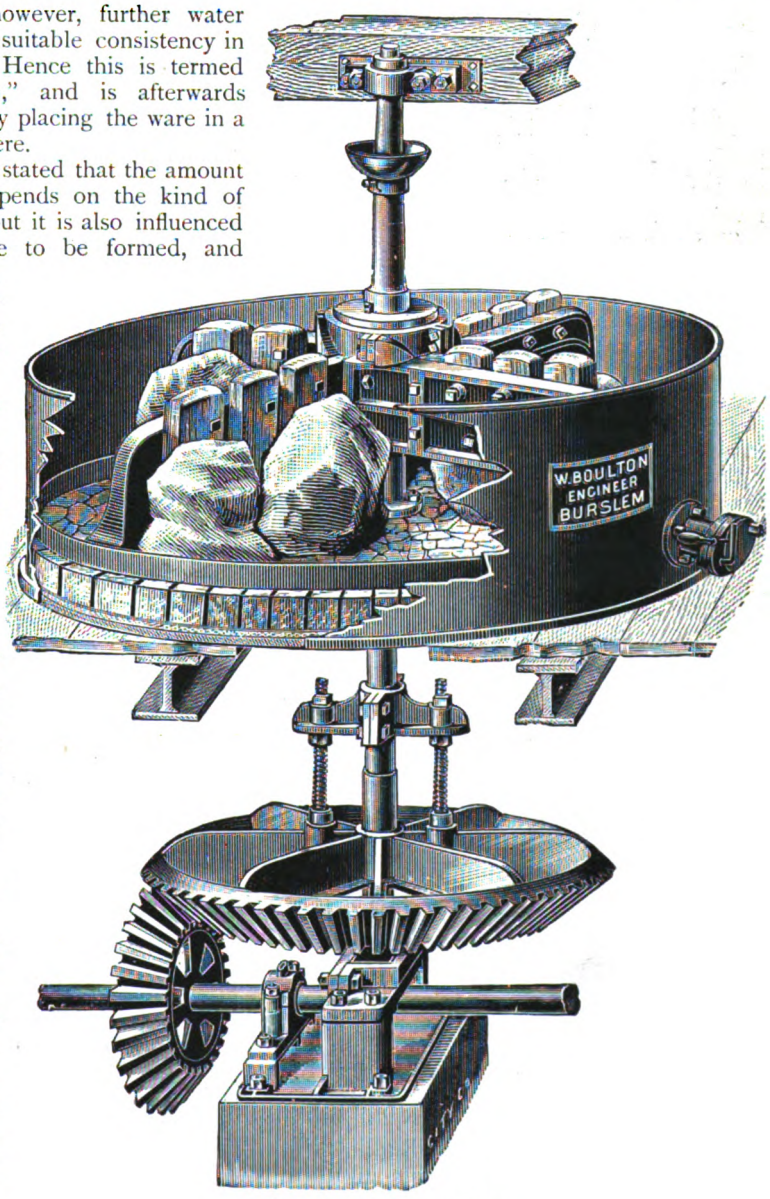

Fig. 1.—Grinding Pan.

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exposed for two or three years to the influence of the weather, being dug over to expose fresh portions, every few months.

All these operations are carried on as a separate manufacture in all except the largest potteries; the materials, finely ground and of ascertained uniformity in consistency and composition, being purchased by the potter ready for use. The advantage of this arrangement is considerable, as it allows him to a great extent to trust to the grinder to maintain uniformity of the material.

In preparing the material two forms of mill are adopted. Until late years the grinding pan represented in the illustration (Fig. 1) was generally adopted. The grinding takes place in water, the upper millstones travelling loosely over a solid stone bed, and being placed in such a position that the whole surface of the bed is traversed at each revolution.

The fine ground materials in a slop state are then sifted through a mesh of standard size, usually 120 to 140 meshes to lineal inch. For convenience this is, when possible, delivered to the potter in the slop state. A uniform proportion of solid material is contained in this slop, the amount being such as to give the best facility for mingling the slops of different materials. This is ascertained by weighing one pint of the slop, which should weigh as follows:—

Flint . . .	31	oz. to the pint.
Felspar . .	31	„ „
Stone . . .	31	„ „
Ball clay . .	24	„ „
China clay .	26	„ „

Another, and very efficient form of grinding mill is now used by many grinders—called the "Alsing Grinding Cylinder" (see Fig. 2). It consists of an iron cylinder lined with porcelain or quartz, which revolves on its longitudinal axis. About one-third of the space within the cylinder is filled with loose porcelain balls or flint pebbles, and one-third with material to be ground, together with sufficient water, the remaining space being left vacant. The orifice is then closed and the machine set in motion for several hours. This causes the pebbles to fall constantly to the lower part of the cylinder as it turns, setting up a grinding movement of all the grinding surfaces against each other, which is found to be far more rapid than that of the mill previously named.

In America and in a few English potteries materials are used "dry ground," no water being added in the cylinder.

Of late years much discussion has taken place as to the influence of dry or wet grinding on the ware produced, and also as to the effect of the size of the particles on the results of manufacture.

These matters are shown to be of very great importance, but, like all others connected with clayworking, become ultimately questions of economy in cost.

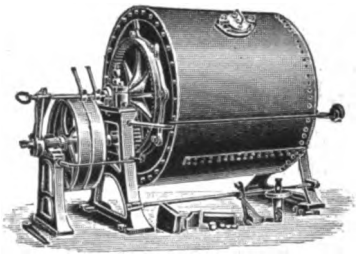

FIG. 2.—THE ALSING CYLINDER.

The consideration of these points must also be qualified by that of the character of ware produced, especially whether this is of a vitreous nature.

Experiments show that, especially in a vitreous body, the grinding of the flint has a very marked effect on the *granular* structure of the ware, but that the grinding of felspar has less.

The *fusing* action of the spar, however, becomes much more powerful by finer grinding.

When flint and spar both occur in the body, if the flint is fine, the influence of the spar is increased whether the spar is fine ground or not.

It has also been shown by Professor Binns that "when in a fused mass of spar there are present a large number of flint fragments, the reflection of these imparts whiteness, and through the spaces between, the light rays can pass; as most of the flint grains are in themselves translucent, a combined whiteness and translucency occurs in the presence of flint, which does not occur in its absence."

The fine grinding of spar has the effect of increasing its power. Hence, finer grinding is an economy of fuel. There is also less danger of blistering. It becomes, therefore, a question whether the extra cost of finer grinding is greater than the cost of fuel saved.

It is found that if the materials are properly ground, the amount of flint may be increased and that of the felspar lowered, thus helping to maintain the same shrinkage and at the same time whitening the body.

The above evidence is therefore strongly in favour of fine grinding of materials. It is,

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however, to be noted that the long-continued grinding of felspars and alkaline frits in water undoubtedly tends to set free a portion of the alkali.

It must also be remembered that the co-efficient of expansion is altered by finer grinding, and change of glaze formula might be thereby involved.

The comparison of size and form of particles produced by wet and dry grinding has been compared with a view of ascertaining

ively through five lawns, and gave the foll w-ing proportions of particles:—

On 120 mesh there was left . .	1·4%
On 140 mesh there was left . .	0·8%
On 150 mesh there was left . .	0·8%
On 160 mesh there was left . .	3·6%
Through 160 mesh there was left	93·4%

Pan ground flint (ground wet) was treated in the same way, and gave the following comparison:—

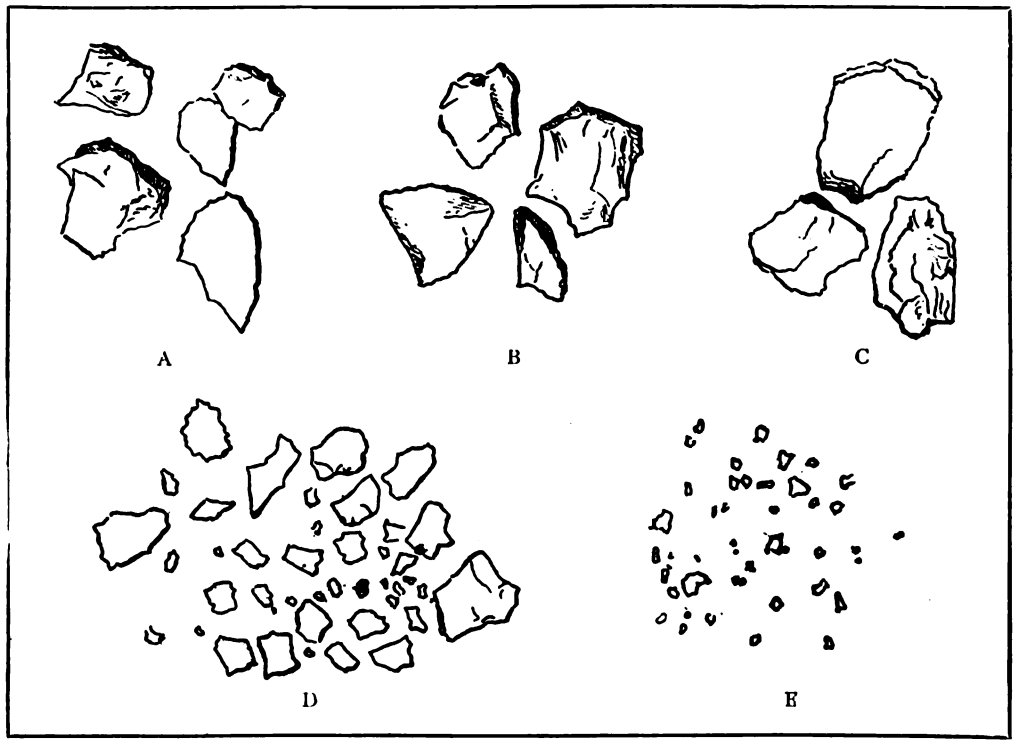

FIG. 3.—GROUND FLINT AND FELSPAR.

A.—*Grains of cylinder ground flint.* C.—*Cylinder ground felspar.*
B.—*Grains of pan ground flint.* D.—*Cylinder flint, dry ground, sifted* 160-*mesh.*
E.—*Same flint as* D, *afterwards wet ground in ball mill, and sifted* 160-*mesh.*
A, B *and* C *are drawn to the same scale.*

the truth of the supposed advantage of the wet process.

Dry grinding does not admit of dry sifting, and this is in some cases a drawback. From the tests given below, however, it appears that the advantage is not all in favour of wet grinding. In estimating the fineness of grinding, the proportion of coarse to fine particles requires careful attention, and the following tests show an important difference in the two methods.

Flint ground dry in an Alsing cylinder lined with wood blocks was washed success-

On 120 mesh there was left. .	3.6%
On 140 mesh there was left. .	4.5%
On 150 mesh there was left. .	4.9%
On 160 mesh there was left. .	2.8%
Through 160 mesh there was left	84.2%

Thus cylinder ground in this case showed a decided advantage as to *grinding*.

Under the microscope *pan* flint shows grains similar in shape to cylinder ground, and experiments do not appear to show the great difference in form of particles usually supposed by potters to exist, the cylinder

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grinding being stated to give globular, and pan grinding angular particles. Neither in flint nor spar is there apparently any appreciable difference in the form of grains.

Comparing flint and felspar treated wet, the following results were obtained :—

Felspar sifted

On the 100 mesh left	3·6%
On the 120 mesh left	1·7%
On the 140 mesh left	2·7%
On the 150 mesh left	1·2%
On the 160 mesh left	2·2%
Through 160 mesh left	88·6%

Mr. Jackson has pointed out the importance of considering the *surface* area of the particles in this inquiry as well as the linear dimension of the particle, and believes that the true value of fine or coarse grinding will be found in calculating the surface areas of the particles of all sizes contained in the bulk.

Washing of Clays.

It seldom happens that ball clays or kaolins in their natural state occur sufficiently pure and uniform for pottery purposes.

Though washing is costly, it gives uniform texture and eliminates all coarse particles, thus saving much loss in ware through defects.

The methods of washing vary according to the nature of the clay. They all, however, involve violent mingling of the clay with water, the removal of coarse particles, and the depositing of the clay slip in the cisterns for use.

The clay is usually placed in a tank or cylinder, and reduced to a pulp or slip by beaters or paddles affixed to a rotating shaft which may be vertically or horizontally placed.

The coarse particles may be removed either by settling and decanting or by sifting.

For clays containing a large proportion of stones or gravel, it is necessary to fit the paddles in such a manner as that these can be removed or raised higher, as the coarse portion accumulates. After a time the mill is stopped for clearing away this residue.

The Apportioning of Non-plastic Material.

The amount and size of the non-plastic particles have important influence on the shrinkage and porosity of the mass. This demands greater attention in the manufacture of goods of coarse texture, such as bricks, tiles, pipes, and terra-cotta.

It is obviously possible to reduce the proportion of non-plastic particles to such an extent that these are wholly surrounded and separated far from each other by the plastic medium.

In this case the grains of sand being solid, and without shrinkage, the porosity of the whole mass and the shrinkage of the mixture will be less when dry than it would have been in the case of unmixed clay.

On the other hand, the amount of non-plastic grains may be so considerable that there is no longer sufficient plastic medium to cover and separate them, and they must, therefore, touch each other at certain points.

Under these conditions the drying of the moisture out of the clay pulp will cause shrinkage. But this only influences the space between the non-plastic grains, and the more the clay pulp shrinks the smaller the space it can fill between the grains; so that small cracks are formed and the porosity of the clay mass is increased by these cracks.

The more the non-plastic portion is increased, the less the clay is sufficient to fill the space, the greater the amount of cracks, and hence the greater the porosity of the mass.

It is under such conditions, therefore, that the actual shrinkage of the manufactured article in drying is reduced to a minimum.

From a series of experiments made by Aron, when investigating this subject, the following result was obtained :—

A fine washed clay mixed with increasing quantities of sand of uniform size, being measured and weighed both when drying and dry, showed that if an equal amount of water is evaporated from the paste, in proportion as the sand is increased the shrinkage at first rises, and the mass becomes closer *up to a certain point;* but then by further increase of sand the shrinkage diminishes, though the porosity becomes greater.

The size of the grains of non-plastic material also considerably affects the shrinkage and porosity of clay mixtures.

Olschewsky shows that when the amount of opening material is uniform the shrinkage in drying is smaller as the coarseness of grain increases.

Aron has compared the result of mixing fine and coarse grains of non-plastic material in the mass. In this case also the shrinkage increased at first, then after a certain addition the shrinkage was less.

Also under the same condition the porosity at first decreased, but became greater from the point when the shrinkage became less.

From this it will be seen that the mass

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was less close than with the coarse-grained material, owing to the fact that the coarser grains of sand are *free* from pores, but the finer grains themselves form pores with the clay particles.

The closeness of the mass, therefore, increased as the size of the grain was finer.

The Tempering of Clay.

In preparing a clay body for use it is important not only to apportion the various materials correctly, and (as already pointed out) to reduce the particles of the body mixture to a definite size, but also to add to the mixture the most suitable amount of water to develop plasticity.

It is necessary to remember that only the clay portion of the mixture lends itself to plasticity. The clay particles move readily over each other when separated by a slight film of water; but this movement only takes place to a very limited extent with non-plastic materials. Hence the amount of water required to promote the most plastic condition is greater in proportion to the amount of pure clay it contains.

It will also be found that the larger the amount of the non-plastic particles the less the amount of water required to induce plasticity in the body.

The proportion of water required in tempering the mass therefore depends on the following considerations:—

1. The proportion of non-plastic material.
2. The size of the non-plastic particles.
3. The amount of plasticity required in the manufacture.

In considering the amount of plasticity required in the mass, it is necessary to enquire first the method of formation to be adopted. Thus the amount of water required for clay to be used on the thrower's wheel is less than for clay to be formed by the "jolley," and the amount of water required for hand-pressing in plaster moulds is greater than that needed for machine-pressing through a die.

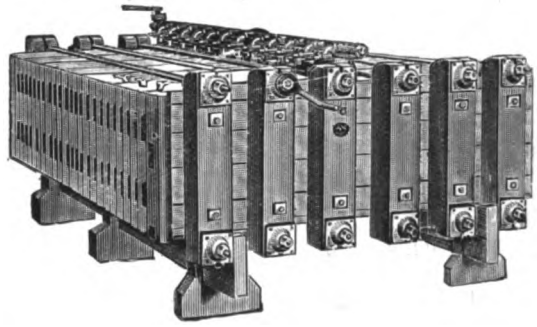

Fig. 4.—Filter Press.

The more water added the greater the space between the clay particles, and the more readily the particles will move over each other. On the other hand, after a certain point, the greater the proportion of water, the less the cohesion of the particles of the mass, until finally the mass assumes a pasty or even fluid condition, being unable to retain its form. In such a state, the clay is used for slip-casting of ware.

On the other hand, it is possible to reduce the amount of added water to so low a point that there is not sufficient to make the mass plastic, but merely to cover the outside of the grains with moisture sufficient to make them coherent at the point of contact. In such a condition the clay is used for making machine-pressed dust tiles.

The Stiffening of Pottery Bodies.

It has already been stated that the proportion of water required in forming the body varies with the different methods of manufacture. The abstraction or the addition of the requisite amount, therefore, needs accurate adjustment.

The stiffening of bodies previous to formation may be accomplished in three ways:—

(*a*) To a portion of clay slip or soft body the requisite proportion of dry ground material may be added to obtain the requisite stiffness. The dry ground portion may be so arranged that it contains the whole of the non-plastic material needed to form the body. Thus in brick-making the marl often comes from the hole in soft mud state, dry sand added stiffening the body for all purposes. The mingling of dry and wet portions of the body may in this case be done most efficiently through rollers feeding into a pugmill, or if required softer, in a mortar mill.

(*b*) If the whole of the ingredients are already mingled in a slop state, the superfluous water may be got rid of by *evaporation*. In hot countries, and in places where there is sufficient space, this is carried on in the open air, the slop being run into large tanks and left to stiffen. As a rule, however, heat is employed, the slop being run into a shallow tank built of fireclay slabs, under which heated flues are carried in such a manner that the slop is heated to about 70° C., being also occasionally stirred, so that the more liquid portions are brought into contact with the heated bottom. When sufficiently stiff it is made homogeneous in a pugmill.

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c) The methods named above give results very irregular in consistency, and the use of the *Filter Press* for this purpose has, therefore, been generally adopted. An illustration of this apparatus is shown in Fig. 4. The principle of its action is based on the forcing of the water particles contained in the slip through the meshes of a canvas cloth, which meshes, though large enough to pass the water, are too small to allow the clay also to exude. The cloths or bags are placed between alternate perforated wooden trays. Nozzles or inlets are fastened to the bags, which are connected with a supply pipe from a force pump. The whole series of alternate bags and trays are clamped strongly together into one rectangular block, after which the clay slip is pumped into the bags through the nozzles. As the pressure in the bags increases the water is squeezed out, and the clay particles remaining in the bag cause the mass to stiffen. The process takes from 2½ to 4 hours. When complete, the clamps are unlocked, the wooden trays removed, the bags unfolded and washed, and the plastic clay removed in thin cakes. This is afterwards pugged to make it homogeneous.

(*To be continued.*)

PETROL-ELECTRIC SELF-PROPELLED RAILWAY COACHES.

THE self-propelled petrol-electric railway coaches recently built by the North-Eastern Railway Company, form the subject of a very successful and interesting experiment. They have done some very good running to time-table, but have not yet been put into service for the conveyance of passengers. Each coach is 50 feet long over buffers, and carries 52 passengers. The coaches run on two four-wheeled bogies, and weigh 35 tons each. The propelling mechanism consists of a four-cylinder horizontal petrol engine, developing about 100 b.h.p., located in an engine-compartment at one end of the coach; the engine is direct-coupled to a 55-k.w. generator, which generates current nominally at 550 volts to supply tramway motors driving on to one pair of wheels of each bogie. The generator is independently excited, a small exciter being driven by a belt. A battery of accumulators drives the generator as a motor, at a reduced speed, for starting the petrol engine, and also supplies current for the lights, and for a motor driving the Westinghouse brake compressor.

In addition to this machinery the engine room also contains the petrol tank, water tank, radiator for cooling the circulating water, and fan to induce a draught of air through the radiator when the coach is standing, the main switchboard, and a tramway controller for driving the coach engine-room forward.

A platform at the opposite end of the coach carries another controller, so that the vehicle can be driven equally well in either direction. Each coach is equipped with a Westinghouse air brake, as well as a special form of electric brake. These coaches can develop a speed of 40 miles per hour on the level, and can successfully negotiate any gradient on the North-Eastern Railway Company's system.

The system of series parallel electric control adopted gives a very rapid acceleration on starting, and constitutes one of the chief advantages of this system over the self-propelled steam coach.

The fuel used is petrol of a density of about 0·725; and as the engines only use one-tenth gallon per b.h.p. hour, and water is only used for cooling the cylinders, sufficient fuel and water can easily be carried for a full day's run.

An efficient silencer for the engine exhaust is slung underneath the coach, and a pipe is carried up through the roof, but as the exhaust is invisible the coach appears, to the casual observer, quite like an ordinary one. The engine, having four cylinders, is very well balanced, and runs extremely quietly, so that travelling in the coach is as pleasant as in an ordinary train.

These coaches are intended to maintain a frequent and rapid service on short journeys with many stops, so as to deal rapidly with suburban traffic and compete with the electric trams.

If they prove successful they will be extensively used in sparsely populated districts where it does not pay to run a frequent service of ordinary trains, so that such districts may be better served at less cost than at present.

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HAND WOOL-COMBING IN THEORY AND PRACTICE.

By ALDRED F. BARKER, Professor of Textile Industries, City of Bradford Technical College.

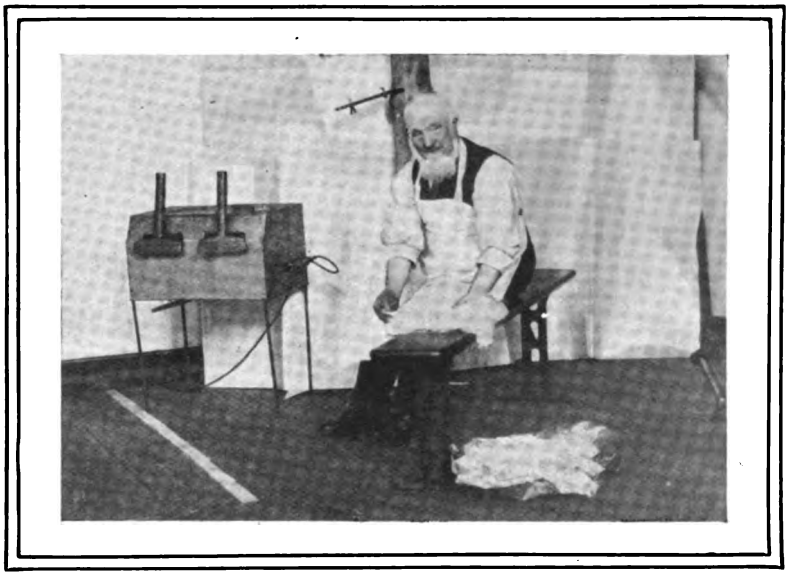

FIG. 1.—MAKING-UP.

THE principles of Hand-Combing are worthy of the fullest consideration: so much is involved in the simple round of operations that time here spent will be saved many times over when studying the machine comb. The overlooker who understands hand-combing can see and feel what is happening in his more elaborate machine-comb, and is practically certain to use his comb to greater advantage, and to treat his material better, than the overlooker who has not taken the trouble to make himself conversant with hand-combing.

FIG. 2.—JIGGING-ON.

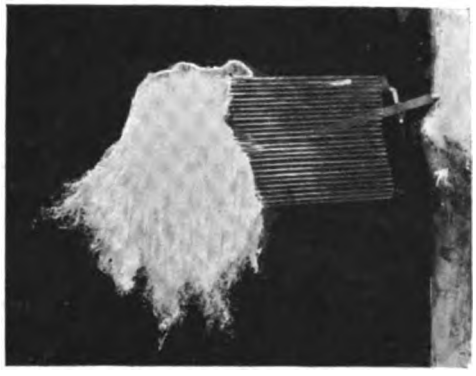

FIG. 2A.—COMB NO. 1 CHARGED WITH WOOL.

DESCRIPTION OF HAND-COMBING.

The following fourteen processes or stages are to be noted :—

1. Making up. (Fig. 1.) (Both combs heating in the pot.)

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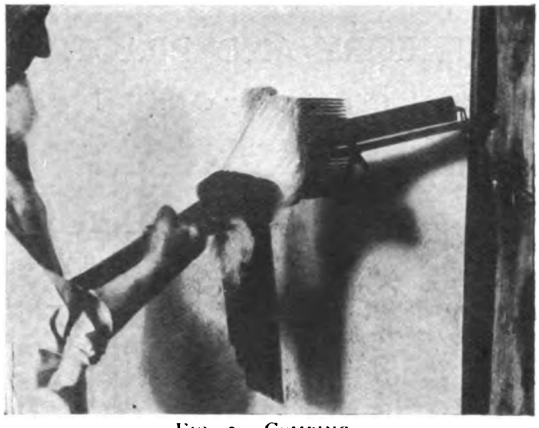

FIG. 3.—COMBING.

2. Jigging on to comb No. 1—as far up as possible. (Figs. 2 and 2A.) Staples must be all arranged lengthways.

3. Combing by means of comb No. 2, assisted by taking hold of staples in comb No. 1 with left hand. (Fig. 3.)

4. Feeding on to comb No. 1 from combing on comb No. 2. (As many times as judged necessary.) (Fig. 4.)*

5. Pushing of tufts to about half-way up the comb for drawing off. (Fig. 5.)

6. Drawing off sliver from bottom to top. (Figs. 6 and 6A.) (Comb No. 1.)†

7. Drawing off milkings and backings. (Comb No. 1.) (Fig. 7.)

8. Clearing off noil (comb No. 1). (Figs. 8 and 8A.)‡

FIG. 4.—FEEDING FROM COMB NO. 2 TO COMB NO. 1.

9. Operations 5, 6, 7, 8 on comb No. 2.§

10. Second making-up. Handfuls to form layer on bench—addition of oil, or oil and water—again handfuls to form layer—again addition of oil, or oil and water. (Fig. 9.)‖

11. Straightening one comb by the other, as in third operation.

12. Drawing off sliver through bone ring to about 2 yds. in length. (Figs. 10 and 10A.)¶

13. Rolling up into balls or "tops." These usually run about 10 slivers to the lb. About 12 slivers form a "top." About 20 lbs. thus treated before the next operation. (Fig. 11.)

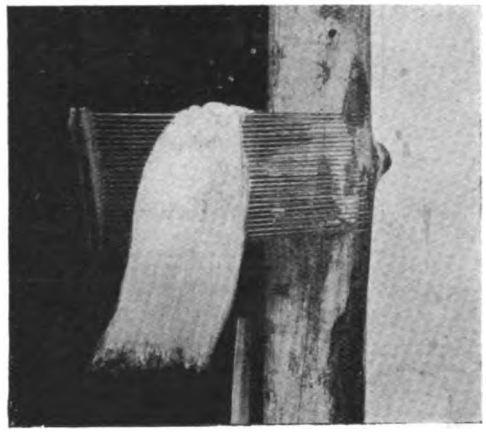

FIG. 5.—WOOL ON COMB NO. 1.

14. Picking out knots, etc., by means of teeth. The slivers or "tops" may now be said to be ready for feeding into the gill box.

Careful consideration of the foregoing details will reveal many points of interest, to many of which it is impossible to refer. Take, for example, the "making-up" for No. 10 operation. To effect this satisfactorily, at least two slivers must be employed, *and they must be reversed, i.e.*, turned head to tail. The reason for this will be apparent if the drawing-off operation (Figs. 9 and 9A) is considered; for it will be evident that although the drawing-off is from the bottom to the top of the comb, yet, generally speaking, the

* Thus there is a combed sliver to be drawn from each of the combs—comb No. 2 tilted—in comb pot.

† This sliver, termed the "jigging-sliver," should be from 2 to 4 yds. long.

‡ Empty comb No. 1 put into pot to warm.

§ Empty comb No. 2 put into pot to warm. About 2 lbs. of wool treated thus before next operation.

‖ Reversing and pulling from two slivers.

¶ Irregularities should be avoided both lengthways and crossways.

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FIG. 6.—DRAWING-OFF COMB NO. 1.

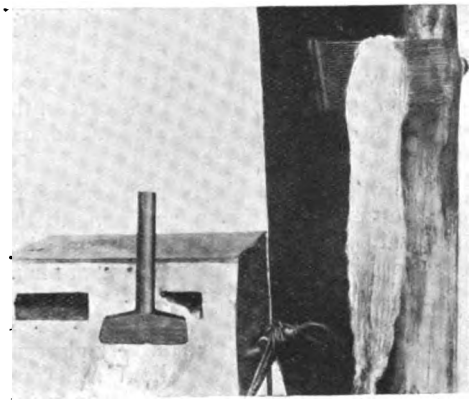

FIG. 6A.—JIGGING SLIVER ON COMB NO. 1.

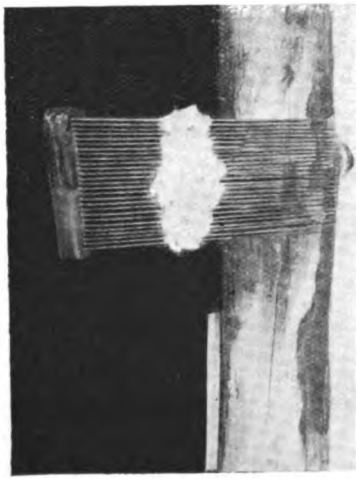

FIG. 7.—BACKINGS AND MILKINGS ON COMB NO. 1.

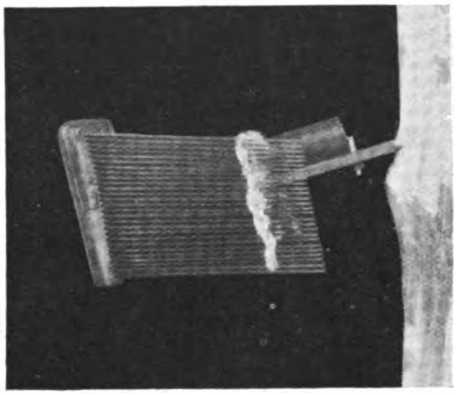

FIG. 8.—NOIL ON COMB NO. 1.

long fibres will be drawn off first and the short fibres last; hence the need for reversing the "jigging-slivers" in the second making-up, *i.e.*, if even distribution of long and short fibres is to be ensured. This useful example will no doubt suggest to the reader other lines of thought equally important and interesting.

IMPLEMENTS EMPLOYED IN HAND-COMBING.

The reader will now be able to understand the requirements of the Hand-Comber. A brief explanation of these will be ample for our present purpose.

1. *The Hand-Combs.*—A pair of these

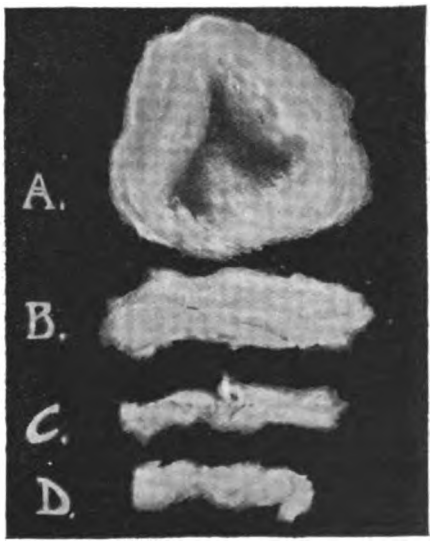

FIG. 8A.—SLIVER, BACKINGS, ETC., FROM COMB NO. 1.

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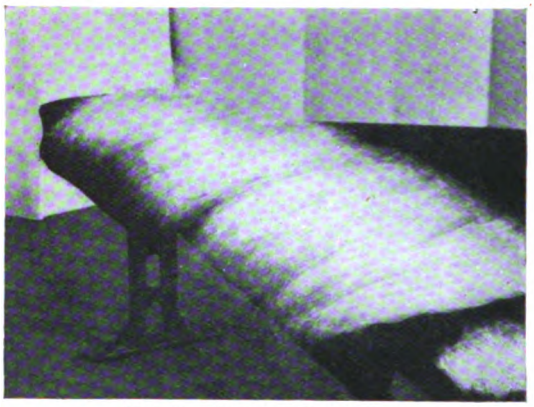

FIG. 9.—SECOND MAKING-UP.

were necessary for the combing operations. Each comb consisted of three or more rows of pins—according to the quality of wool to be combed, of three or more heights—to enable the comb to easily penetrate the wool to be combed; so far as possible set in bone,

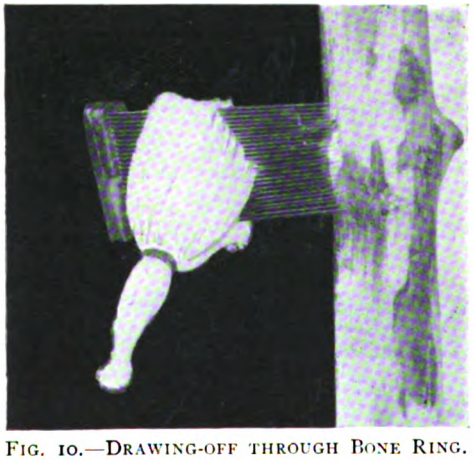

FIG. 10.—DRAWING-OFF THROUGH BONE RING.

to enable the comb teeth to retain as long as possible the necessary heat taken from the comb pot; and with a suitable wood handle socketed to fit with a slight upward inclination of the teeth on to the staple or holder on the pad-post. Combs were made of various weights, but the ones shown in the illustration weigh 6 lbs. each.

2. *The Pad-Post.*—The necessity for the use of this is so evident from the illustration, that no further reference is necessary here.

3. *The Staple, or Comb-holder.*—This is so arranged that the comb, when in its working position, is firmly held, but when required off the "pad-post," a simple sliding and lifting action frees it. Of course the grooves in the comb handle and the angles on the staple must be fitted, the one to the other, to ensure this.

4. *The Comb-Pot.*—This was made in many forms, but really there were only two distinct types, *viz.*, the pot heated by coal, with inlet and outlet; and the pot heated by charcoal, without a chimney. Both these types will be noticed in the illustrations. The true type is shown only in Fig. 12A. As a rule, the pot appears to have been a "pot o' four," at which two combers would heat their combs.

5. *The Making-up Bench.*—This was simply a long plank upon which making-up could be conveniently accomplished. Fig. 9 shows this clearly, and it is further shown in last month's TECHNICS, Fig. 4, p. 184.

6. *The Bone Ring.*—This, as will be noticed from Fig. 10, was about 1½ inch across, the hole through which the sliver was drawn being about 1 inch by ¾ inch.

There would, no doubt, be many variations from the types here shown, according to the individual fancies of different combers; but the main principles of hand-combing are here clearly defined, and the necessary apparatus indicated. It may be of interest to readers to mention that the operation is a very pleasant one to perform, requiring both skill and experience—the two great factors producing interest in our work as in our sports.

CONDITIONS UNDER WHICH WOOL WAS COMBED BEFORE 1840 TO 1850.

The following notes, kindly made for these articles by Mr. Cudworth, a well-known Bradford archæologist, will give the best idea of the conditions under which wool was

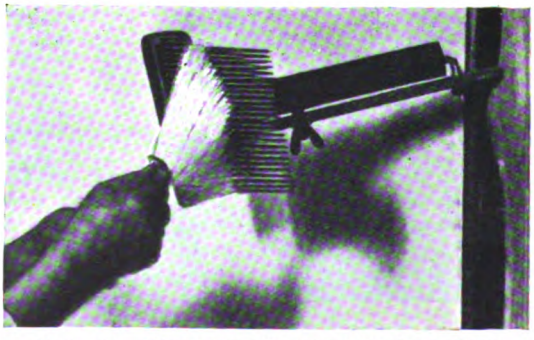

FIG. 10A.—DRAWING-OFF THROUGH BONE RING.

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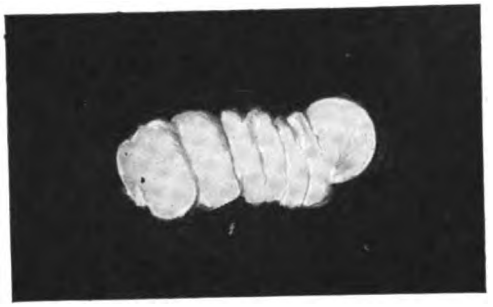

FIG. 11.—A ROLLED-UP "TOP."

FIG. 12.—WOOL-COMBER'S CERTIFICATE.

combed in the best days of the hand-combing period.

NOTES MADE ON INTERVIEW WITH THOMAS FOULDS, A BRADFORD WOOL-COMBER FROM 1825 TO 1850.

He was brought up to wool-combing under his father, who also was a hand wool-comber, first at Frizinghall, for Messrs. Hargreaves, and afterwards at Bradford, for Messrs. Rouse, Rand, and others.

He got his wool in the raw state, along with a can of oil required in the process of combing, which he conveyed home in a "fadge," or pack. He was allowed a pair of wool combs (property of his employers) and a certain quantity of charcoal required to feed the comb pot or "pot o' four" for heating the wool-combs.

He was required to return to his employers a certain recognised weight of the combed wool, either in the finished "sliver" or in short wool or "noil," which latter had not sufficient length of staple to form part of the sliver.

Before the introduction of Colonial wool, the wages of hand-combers were very low, and £1 a week was considered good remuneration.

When Colonial wool came in, much greater care was required, and better wages were

FIG. 12A.—ENLARGEMENT FROM WOOL-COMBER'S CERTIFICATE.

earned by the hand-comber; until, of course, this industry was completely knocked on the head by the introduction of the combing machine.

Thomas Foulds was paid as much as

FIG. 13.—BISHOP BLAIZE FESTIVAL OF 1811.

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2s. 6d. a pound for combing, by hand, fine Colonial wool.

[As the raw material would probably cost an additional 2s. 6d. per lb. in addition to other expenses and employers' profit upon invested capital—*Query:* What would be the price per lb. of the finished yarn spun from this wool?]

Thomas Foulds was one of the last employed at the now obsolete work of hand wool-combing, inasmuch as he was specially retained by the late Sir Titus Salt to comb certain wools required to form part of high-class fabrics intended for the Saltaire display of Bradford-made fabrics at the Great Exhibition of 1851. He was paid 1s. 6d. a lb. for combing, by hand, alpaca wool intended for the same exhibition.

The comb pot, or "pot o' four," was generally of very thick clay, lined inside with brick in that portion holding the fire. This portion was covered over with an iron plate, above which was a hollow space with outer openings to admit the four combs and to heat them.

The exterior of the comb pot was generally hooped round with sheet-iron hoops, to keep the body of the pot together. In addition to this, slabs of wood were placed round it to keep any wool left on the combs (see Fig. 12A) from coming in contact with the heated comb pot.

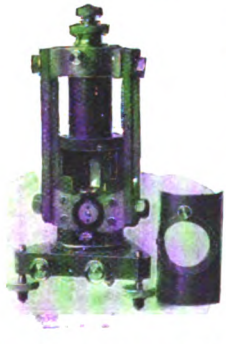
For English wool each comber was provided with two pairs of combs. The "jigging sliver" was made upon coarse 3-pitch combs. The same wool was then "straightened," or "finished off," on 4-pitch combs.

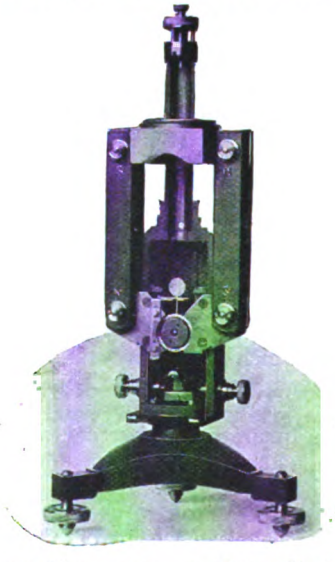
For Colonial wool, in place of 3 and 4-pitch combs, 5 and 6-pitch combs.

The difficulties of constructing a machine to effect the above noted cycle of operations were naturally many. In subsequent articles the first strivings in this direction will be dealt with in considering the work of Dr. Cartwright. How ultimately success was achieved by Lord Masham, will form the subject-matter of the last article of the series.

NEW SUSPENDED COIL GALVANOMETERS.

SINCE a modern electrical laboratory can scarcely be protected from magnetic disturbances, delicate suspended magnet galvanometers cannot generally be used; it is fortunate that, in the suspended coil galvanometer, we have an instrument as delicate as those of the suspended magnet type, while practically unaffected by magnetic disturbances. The earlier suspended coil galvanometers were either unnecessarily cumbersome, or else difficult to adjust and extremely sensitive to vibrations. The accompanying illustrations show two latest forms of galvanometer designed by Mr. Clark Fisher, whose book on the Potentiometer is so well known to those engaged in electrical testing. A glance at these illustrations will show (what might have been anticipated) that Mr. Fisher has designed his instruments with a special view to compactness and readiness of access





to all working parts, so that adjustment is rendered easy and certain.

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ELECTRIC WAVES.

PART II.—PRELIMINARY EXPLANATIONS (*continued*).

By J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London.

IN the August number of TECHNICS I briefly discussed the properties of the æther, especially those which must be assumed in order to explain electric and magnetic phenomena. It was pointed out that the magnetic and electric properties of the æther, though distinct from each other, are not independent; and an attempt was made to convey definite ideas as to the relation between them.

These ideas may be rendered more definite by attention to certain mathematical definitions. Let us consider any vector quantity which has distribution in a certain region, which for the sake of simplicity we may consider to be a plane. Suppose the vector represents the velocity of the water particles on the surface of water. Draw any rectangular area (see Fig. 1) whose sides are dx and dy. Let V be the vector, and let its rectangular components X and Y be the resolved parts along dx and dy. Then at the origin O we have as components of V the rectangular vectors X and Y.

At the opposite ends of the diagonal the component vectors are $\left(X + \frac{\partial X}{\partial y} dy\right)$ and $\left(Y + \frac{\partial Y}{\partial x} dx\right)$, by Taylor's theorem. Suppose now that we take the *line-integral* round this rectangle, that is, march round it and multiply the length of each side by the component of the vector along that side, the product being reckoned *plus* or *minus* according as the vector direction is with or against the movement. We obtain for the sum of these products the expression: —

$$X\,dx + \left(Y + \frac{\partial Y}{\partial x} dx\right) dy - \left(X + \frac{\partial X}{\partial y} dy\right) dx - Y\,dy = \left(\frac{\partial Y}{\partial x} - \frac{\partial X}{\partial y}\right) dx\,dy.$$

The quantity $\left(\frac{\partial Y}{\partial x} - \frac{\partial X}{\partial y}\right)$ is called the *curl* of the vector V in the plane (x, y).

The above theorem when expanded for three dimensions is a very important one, and may be enunciated as follows:—

The line integral of the vector round the boundary of an area is equal to the surface integral of the curl of the vector over the area. This theorem, being due to the late Sir G. G. Stokes, is called *Stokes's Theorem*. In some cases the line integral of a vector round any boundary is zero, and the vector is then said to have a potential but no curl. In general the curl of a vector has different magnitudes in different planes, but the maximum curl is generally called "the curl" of the vector. The curl has often a physical meaning. Thus, for instance, if the vector itself represents the velocity of a spherule of a liquid in motion, the curl of the velocity represents twice the angular velocity with which the spherule is rotating. Hence, if the curl is zero, the motion of the liquid is irrotational. In the subject of electromagnetism we are concerned with two principal vectors and their curls, and the relations of these to each other.

We shall find it convenient at this point to introduce the notion of *electric and magnetic*

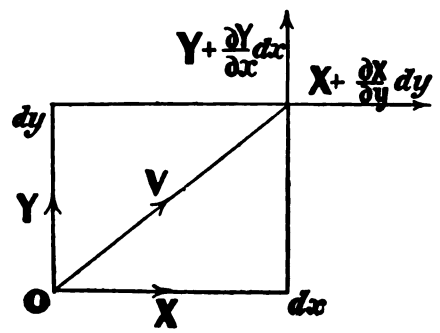

FIG. 1.

force. We have explained that the æther has two qualities, called its permeability (μ) and dielectric constant (k), and that we can produce in it two physical states, called the magnetic flux (B) and electric strain (D). At any place these quantities have certain numerical values. The numerical quotient of B by μ is called the magnetic force (H); and the numerical value of D divided by k is

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called the electric force (E). Hence the fundamental equations defining E and H

$$4\pi D = kE \text{ and } B = \mu H.$$

These are the usual definitions. In Mr. Oliver Heaviside's rational system of units the 4π in the first equation is eliminated.

We have then two line integrals to consider. The line integral of the electric force taken round any boundary is called the *electromotive force* in that circuit; and the line integral of the magnetic force round any boundary is called the *magnetomotive force*, and this, by a theorem due to Ampère, is equal to 4π times the current through the boundary.

Again we have to consider two time rates of change. If the magnetic flux (B) through any area is changing with time, we can denote this by a dot put over the B, thus, $\dot{B}$, and for the sake of brevity call this the flux change. In ordinary notation the flux change is denoted by $\partial B/\partial t$.

Faraday showed that the result of making a flux change in the interior of a conducting circuit was to produce a numerically equal electromotive force round the circuit. Hence since the electromotive force is the line integral of electric force, we have the relation *flux change = line integral of electric force*. In mathematical symbols this is expressed by the equation

$$-\frac{\partial B}{\partial t} = \text{curl } E.$$

The minus sign is prefixed to express the relation between the direction in which B is decreasing and E is acting.

Furthermore, Maxwell established the principle that if the displacement or electric strain is varying with time, its time-variation, or the displacement change, is equivalent to an electric current. Hence by Ampère's law we must have

$$4\pi \frac{\partial D}{\partial t} = \text{curl } H$$

which expresses the fact that 4π times the displacement current through a unit of area is equal to the line integral of magnetic force round that area. These last two equations can be reduced to greater symmetry by noting that $4\pi D = k E$, and $B = \mu H$ by definition. Hence by substitution we have

$$k\frac{\partial E}{\partial t} = \text{curl } H, \text{ or } k\dot{E} = \text{curl } H$$

and $$-\mu\frac{\partial H}{\partial t} = \text{curl } E, \text{ or } -\mu\dot{H} = \text{curl } E$$

as the fundamental equations governing the relation of magnetic and electric force in non-conducting space.

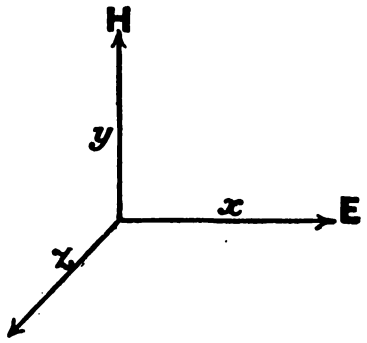

FIG. 2.

Let us illustrate the solution of these equations by considering a very simple case. Let the electric force be everywhere parallel to the axis of x, and the magnetic force parallel to the axis of y, whilst the axis z is towards the reader (see Fig. 2).

Then we have

$$\text{curl } E = \partial E/\partial z$$

and

$$\text{curl } H = -\partial H/\partial z,$$

thus

$$k\frac{\partial E}{\partial t} = -\frac{\partial H}{\partial z} \quad . \quad . \quad . \quad \text{(i.)}$$

and

$$\mu\frac{\partial H}{\partial t} = \frac{\partial E}{\partial z} \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

The above two equations can easily be transformed, by differentiation with respect to t and z, into

$$\frac{\partial^2 H}{\partial z^2} + \mu k\frac{\partial^2 H}{\partial t^2} = 0 \quad . \quad . \quad \text{(iii.)}$$

$$\frac{\partial^2 E}{\partial z^2} + \mu k\frac{\partial^2 E}{\partial t^2} = 0 \quad . \quad . \quad \text{(iv.)}$$

The above are well-known equations in physics. They are precisely of the form of those which express the propagation of a wave of sound along a tube, and they are satisfied by the solutions

$$E = E_0 \cos 2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right) \ldots \text{(vi.)}$$

$$H = H_0 \cos 2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right) \ldots \text{(vii.)}$$

where $\frac{T}{\lambda} = \sqrt{\mu k}$, and $E_0\sqrt{k} = H_0\sqrt{\mu}$

The student can easily prove this by differentiating (vi.) and (vii.) with respect to t and z, and proving that these differentiations comply with (iii.) and (iv.). These equations (iii.) and (iv.) are therefore the mathematical expressions for a wave of electric and magnetic force propagated along the axis of z with a

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velocity $1/\sqrt{\mu k}$, *viz.*, with the velocity of light.

At this stage the student should endeavour to appreciate fully what is meant by a "wave" in mathematical physics. A wave motion in a medium may be defined as a variable state which, along any line, is periodic in space; and at any point is periodic in time. At any point the displacement has a certain maximum value which is called the amplitude. Hence, if y denote this displacement, and Y the amplitude, the proper expression for y at any distance x from the origin, and at any time t is a periodic function of the form

$$y = Y \cos 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right) \quad . \quad . \quad . \quad \text{(ix.)}$$

where T is the periodic time and λ the wave length and λ/T the velocity of the wave motion.

Now the characteristic of a wave motion is that if we consider ourselves to move forward at the same rate as the wave, the wave appears to be stationary. If, for example, a bird flies along parallel to the sea surface in the direction in which waves are moving, and with the same velocity as the waves, the sea surface would appear to the bird to be quite at rest.

Hence, if the equation (ix.) represents a wave, it must remain unaltered if we increase x by an amount x_1 and at the same time t by an amount t_1 such that $x_1/t_1 = \lambda/T$.

But

$$\frac{x + x_1}{\lambda} - \frac{t + t_1}{T} = \frac{x}{\lambda} - \frac{t}{T}$$

if we put $t_1 = x_1 \frac{T}{\lambda}$.

Hence the theorem is proved, and the function $y = Y \cos 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)$ is the proper mathematical expression for a wave motion.

In the case of electric waves we are not concerned with actual displacements and velocities, but with electric and magnetic forces.

Hence an electric wave consists of a periodic alternation of electric strain and magnetic flux taking place along a certain line, such that the electric strain and magnetic flux are at right angles to each other and to the line of propagation. The electric strain is a maximum when the magnetic flux is zero; and the flux is a maximum when the strain is zero. At any one point the flux and strain vary periodically, and at the same instant there is a periodic distribution of strain and flux along any line, at right angles to their plane.

The engineering student who is accustomed to making models can assist himself to comprehend this notion by making a cardboard model thus:—

Procure two pieces of stout white card and slit them along their middle for half their

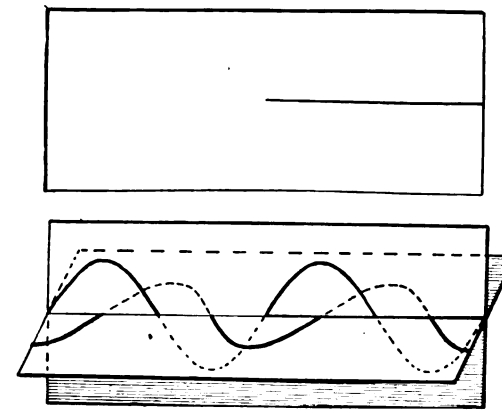

FIG. 3.

length—(see Fig. 3). Then place the pieces so as to form two planes at right angles to each other. On each card describe a wave curve, which is a curve of sines, and draw these curves so that the sine curve on the vertical plane is shifted 90° in phase behind or in front of the sine curve on the horizontal plane.

Let the ordinates of the former represent the variation in space of the electric force, and those of the latter the variation in space of the magnetic force; the line of intersection of the cards represents the direction in which the wave is travelling. Then these two vectors are at right angles to each other; and if we consider the sine curves as defined by the simple periodic motion of points which move up and down or backwards and forwards, one always 90° in phase behind the other, then we shall have a representation of an electric wave in progress.

In comparing an electric wave with a surface water wave or an air wave, we must think of electric strain or force as analogous to water displacement, or air compression or rarefaction; and magnetic flux or force as analogous to water velocity or air velocity.

Before concluding these preliminary explanations, we may point out a mode of viewing the subject which took its rise in an idea suggested by Faraday, and has been mathematically developed by Professor J. J. Thomson of late years.

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It has already been explained that the state we called electric strain in an electric field is distributed along certain lines called lines of strain, or, as Faraday called them, lines of electric force. These lines were regarded by Faraday not merely as mathematical artifices for elucidating the subject, but as real things, something resembling elastic threads connecting two oppositely electrified bodies. If we have a string or thread in tension, like a violin string, then transverse waves can be propagated along it, just as we can send a jerk along a rope.

Professor J. J. Thomson has mathematically expanded this conception, and has shown that the lateral movement of a line of electric strain gives rise to a magnetic field or flux, and also that these electric lines act just as if they were elastic threads, the tension at any point being proportional to the mass per unit of length. Hence a jerk or pulse is propagated along the line of strain with a constant velocity which is that of light. Hence we may picture to ourselves the space round an electrified body, or between two oppositely electrified bodies, as filled with lines of electric strain which are like elastic threads. If this electrified body makes a sudden movement, or experiences a sudden increase or decrease of charge, a pulse or wave is propagated along these lines of electric strain, which resembles the wave or hump which travels along a stretched rope when it is jerked at one place.

From this point of view all electric waves, whether light waves, Hertz waves, or Röntgen rays, are simply pulses or trains of pulses travelling along lines of electric strain in the æther.

This mode of viewing the phenomena enables a simple explanation to be given of the fact that the sudden starting or stopping of an electrified body gives rise to electric waves.

If a small electrified sphere in rapid motion is suddenly stopped, an electric pulse or wave shoots from it. The radiation called Röntgen rays is, with good reason, thought to be produced by the sudden arrest of the motion of the stream of negatively charged cathode particles in a Crookes tube. For a complete elucidation of this theory we must refer the student to a book by Professor J. J. Thomson, called "Electricity and Matter" (Archibald Constable, London).

We shall in the next place proceed to consider how an electric wave is generated.

(*To be continued.*)

In the following numbers of TECHNICS, *Professor FLEMING will describe and explain the latest discoveries and inventions relating to "Electric Waves," with special reference to developments of Wireless Telegraphy.*

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THE RADIO-ACTIVITY OF GAS MANTLES.

By A. F. BURGESS and B. INGRAM, B.A., F.C.S.

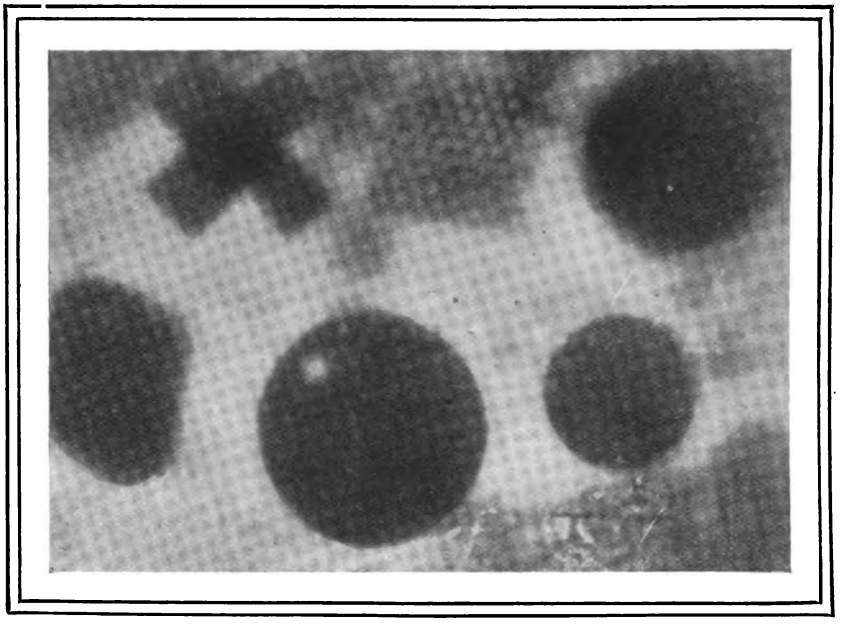

FIG. 1.

THE following experiments may possess some interest, since they can be very easily repeated, nothing more costly than disused gas mantles being required for their performance.

The radiographs (Figs. 1 and 2) were obtained by exposing a photographic plate, covered with layers of ordinary note-paper, to powdered incandescent gas mantles in the dark. The exposures varied from seven to forty days.

Fig. 1 is a print taken from a plate which was exposed in this way for seven days. The articles on it (read from left to right) are :—Aluminium cross with a small copper coin *below* it: perforated zinc : piece of green glass : piece of red glass ; and two copper coins. The printing across the middle of the illustration was produced by the interposition of a strip of newspaper.

One of the most interesting features of this radiograph is the aluminium cross, the central part of which has failed to screen the copper coin below it. It is also curious that the printer's ink was transparent to the rays, and indeed seems to have directly affected the plate in contact with it. This is no doubt the effect investigated some years ago by Dr. Russell.

Fig. 2 is the result of a twenty-eight days' exposure. Here the cross is seen *through* the copper coin. The anchor is a mother-of-pearl brooch, whilst the oval brooch has a centre of bone. To the right of the cross and above the latter is a faint shadow, in the

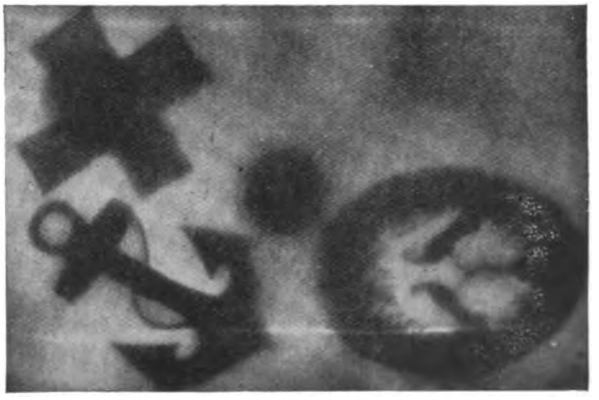

FIG. 2.

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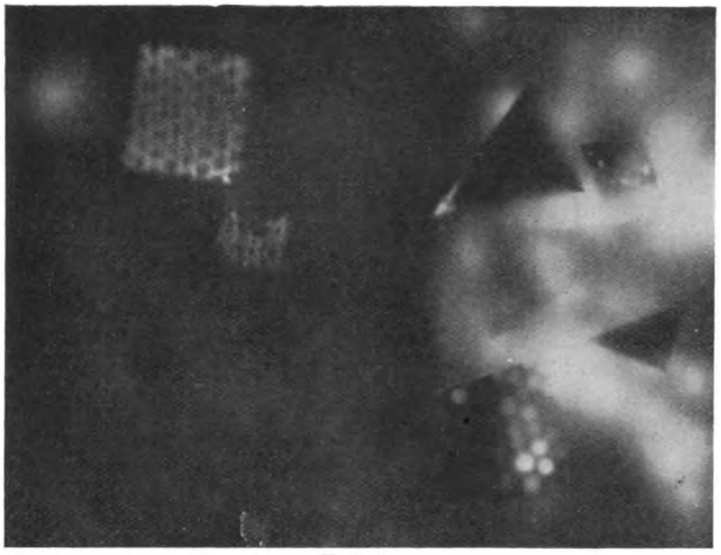

FIG. 3.

centre of which is a square figure; this is due to a piece of leather which failed to entirely intercept the rays.

Fig. 3 is a result of a thirty-nine days' exposure. The right-hand portion was covered with some uranium nitrate crystals mixed with powdered zinc sulphide. The bright spots mark the positions of the crystals. The glow, which gradually fades away from these centres, may be due to the fluorescence of the zinc sulphide in presence of the uranium nitrate. The objects (from left to right) are :— Copper, aluminium, lead, tin, and zinc (perforated).

The left-hand portion of the print shows the result of an exposure to calcium sulphide. The perforated zinc and aluminium appear to have now themselves become sources of emanations; they were the same pieces of metal that had been used for the previous experiments, and had thus been exposed for a considerable time to the emanations of the gas mantles.

A note in the June number of TECHNICS to the effect that the radioactivity of thorium is due to the association of that element with uranium, suggested to the authors the comparison of the rates of discharge of a gold-leaf electroscope by the two elements in question. The results have been represented by graphs.

Fig. 4 shows the results when the uranium nitrate (U) and the mantles (M) are placed *on* the disc of the electroscope.

Fig. 5 refers to the case where the uranium and powdered mantles are placed (successively) *beneath* the leaves.

It will be noticed in Fig. 5 that the rate of discharge is definitely greater for the mantles than for the uranium, *i.e.*, 0·25 grams of the former has the same effect as 1 gram of the latter.

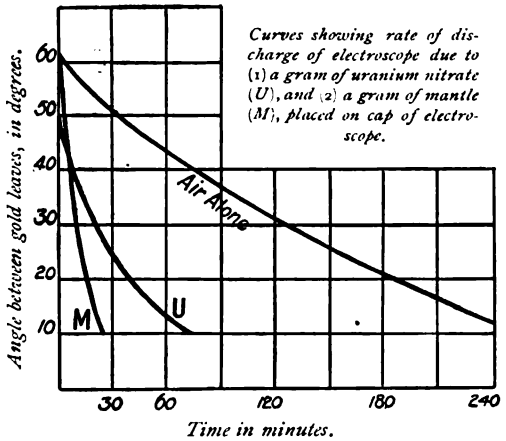

FIG. 4.

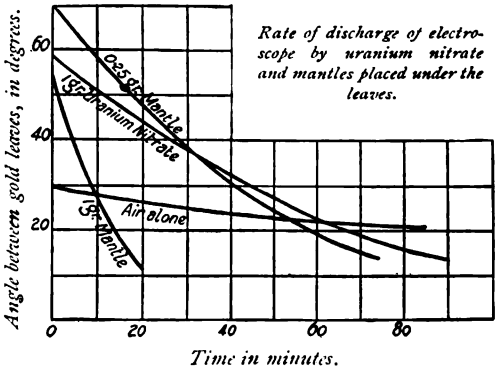

FIG. 5.

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By R. BORLASE MATTHEWS, Wth. Exb.

A GREAT deal of inventive capacity has been used in the construction of commercial arc lamps, and many ingenious designs have been evolved; but very little attention has been paid, in this country at any rate, to the composition and manufacture of the most important parts of the lamp, namely, those between which the arc is produced. Carbon has almost without exception been used for this purpose, and seems to be the most suitable substance; but the term "carbon" covers a wide range of material varying in commercial characteristics, in composition, and in physical state. Arc light carbons may be hard or soft, large or small, cored or solid. The results of experiment show that the lighting power of an arc depends, not only on the current and length of arc, but also on the composition and sizes of the carbons used. The harder carbons containing more graphite give less light for the same power than the softer carbons containing a large percentage of lampblack. This is in all probability owing to the quicker burning away of the softer carbons, which consequently ensures a more distinct crater and a better pointing, both factors in favour of the production of an economical light. The light efficiency increases very rapidly with the diminution of diameter, so evidently small carbons are desirable; though if they be made too small in lamps as they are at present designed, difficulties arise in carrying the current, owing to their length and consequent resistance. They must be made of a certain length, so as to diminish as far as possible the labour of frequent re-trimming. It is this saving of the labour in re-trimming which has caused the enclosed arc to be so widely adopted, though it is not nearly so economical as the open arc. Hence a slow-burning carbon should be aimed at, as this would enable open arcs to be used in many places where enclosed arcs are at present employed. To reduce the resistance, and increase the length of the arc, the carbons are often cored; that is, the centre is filled with a mixture of carbon and certain salts, which forms a path of less resistance than the pure carbon. This has the disadvantage that the light is diminished as the diameter of the core increases, for such a core has a lower degree of incandescence than the pure carbon—a matter of importance, for the greater portion of the light of an arc is given off from the crater. Cored carbons can carry a much larger current without hissing than is the case with the solid carbons, because the vapour

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film, and consequently the crater, is smaller. A special use for cored carbons is in the modern "flame" lamp, where advantage is taken of the long arc which can be maintained by the vaporisation of the salts in the core, in addition to the vaporisation of the carbons themselves. Under present conditions, and with existing types of lamps, two solid carbons are used for alternating current work: a solid negative combined with a cored positive carbon are used for continuous current work.

Not only has the purity, composition, type, and size to be taken into account, but also a great deal of attention must be paid to the mechanical treatment to ensure freedom from such defects as cracks and blisters, variations in size and quality, lack of straightness or want of sufficient baking, inadequate mixture of the material from which they are made, and insufficiently pulverised material.

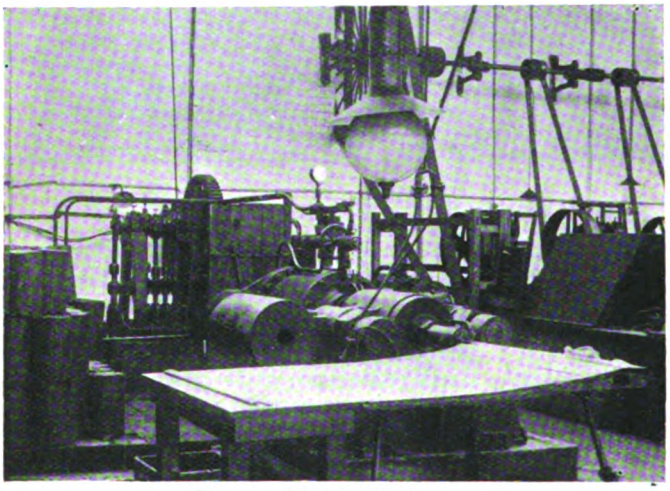

FIG. 1.—HYDRAULIC PRESS.

The foregoing summary briefly shows how many difficulties there are in the manufacture of such an apparently simple thing as an arc light carbon; and the absolute necessity for uniformity of quality, if satisfactory results in burning are to be obtained, and if objectionable features such as the spitting, flaring, flickering, or jumping of the arc light—in as far as they are due to the carbons—are to be eliminated.

The whole of the carbons used in this country were obtained from the Continent until about two years ago, when the General Electric Company started their carbon works at Witton, near Birmingham, thus establishing a new industry in this country, employing nearly 250 workpeople. Starting a new manufacture like this must have called for the solution of many difficult problems, not the least important of which arose from the keen rivalry and competition from the old-established Continental makers. This works is now producing carbons which are recognised to be equal to the best Continental product, in face of prices which have never existed before, and which have only reached their present low level in this country as a direct result of the starting of this factory.

The best Continental practice has been followed in the laying out of these works. Power is distributed electrically from the central power station of the engineering works, motors to the extent of 250 h.p. being installed. The voltage of the supply circuit is 460. Owing to the large amount of carbon dust suspended in the air, the motors in several instances have to be placed outside the buildings.

The first process in the manufacture is that of grinding and mixing the raw materials. Gas coke is first of all passed through crushers, crushing rolls, and other disintegrating machinery, then mixed with graphite and other material, according to the composition finally required; for this purpose it is put into special mixing or kneading machines, where all the particles are brought into intimate contact. The mixture then has a special binding compound added to it, the whole being well incorporated together in a mill, similar to those used for grinding mortar. The next operation is to ram the whole into a cylindrical mould by aid of a drop hammer. The resulting cylinders of material are about nine inches in diameter by fourteen inches long. A pile of these blocks can be seen on the left hand of Fig. 1, which shows one of the hydraulic presses in the press room. The presses used may be described as consisting of three main parts, namely, (*a*) the pressure cylinder, (*b*) the receptacle for the blocks of material, and (*c*) the nozzle through which the carbon composition is forced; the whole being mounted on a very substantial framing and bed. The machine is so constructed that the receptacle

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(*b*) can be swung clear of the hydraulic cylinder when the ram of the latter is right back, so that a fresh supply of material can be inserted without difficulty. To aid the workman in swinging this part over, a suitable balance weight is added on one side: in Fig. 1 this balance weight is clearly shown on the left of the press. Having charged the receptacle, the operator swings it back into place, and then opens the valve, admitting the pressure water, which, by driving the ram into the chamber containing the carbon material, forces this through the nozzle. The nozzle is arranged for heating by steam or cooling by water, according to the exact composition and treatment required for the compound which is being worked upon. Upon issuing from the nozzle, when, of course, it is a continuous rod, it runs over a row of rollers shown at the top of the planed iron table in the foreground of Fig. 1. As the rod comes out, it is deftly cut by hand into easily handled lengths of about four feet. These lengths are then subjected to a preliminary inspection, and put on tables to harden in piles, as indicated on the right-hand side of Fig. 1. They are afterwards subjected to another more careful inspection, and packed in iron cases, which in their turn are put inside special crucibles, the interstices being filled with powdered carbon. A cover is then luted on, and the whole placed in an oven to bake.

A number of these crucibles can be seen on either side of the ovens in Fig. 2: a charged one is just being lowered into an oven.

The ovens are of the continuous baking type, heated by producer gas. The gas-producing plant, which is of the Meiser type with water-sealed cleaning grates, is situated at one end of the building, the gas passing up through a flue between the ovens; the latter, as can be seen from Fig. 2, are arranged in two rows. The capacity of the ovens is about 200 tons; they are used in sets, so that the process may be a continuous one, the mixture of burning gas and air being passed through a set in series, the last of the set being connected to the flue leading to the stack by aid of a pipe, as indicated on the right-hand side of Fig. 2. When the material in the first oven of the series is sufficiently baked, this oven is cut out and another at the further end connected up; thus the ovens in the rear of a set in operation are cooling down while those in front are being re-charged, this method of procedure being carried out throughout the whole range. The temperature to which these ovens are raised varies from 1300° to 1800° Celsius (1625° to 2250° C.) according to the quality of carbon desired. To enable the workmen to estimate the temperature of an oven, a very ingenious form of pyrometer is used, consisting of four pieces of porcelain

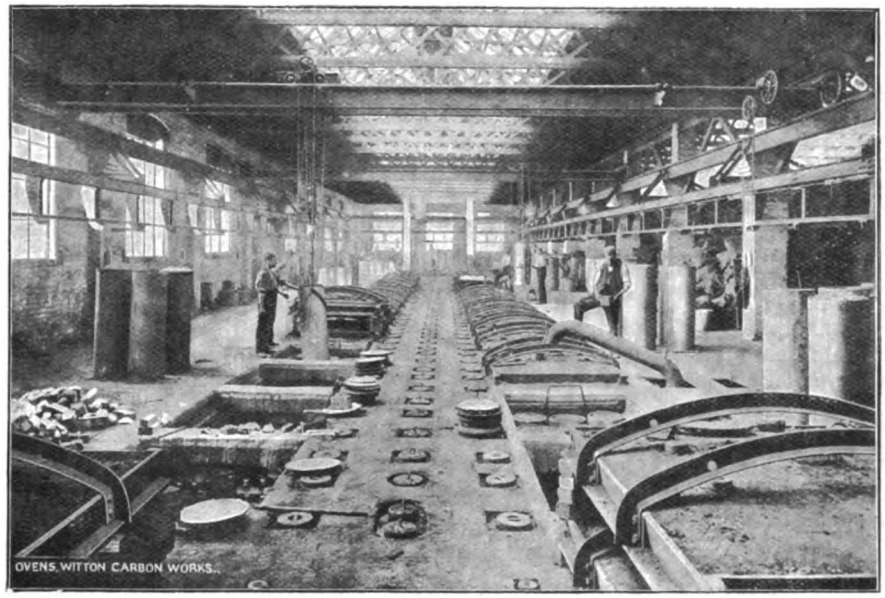

FIG. 2.—OVENS FOR HEATING CRUCIBLES.

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of tusk-like shape made of a carefully graded mixture of silica, each differing slightly in composition from the others, so that there is a difference in their fusion points of about 100° Cel. These pieces are fixed by their larger ends into a piece of fireclay, and put into the oven in such a position that they can be seen through a sight-hole. As the temperature of the oven reaches the fusion point of one of the pieces in the pyrometer, this piece gradually bends over, indicating to the workman that the correct temperature has been reached. Fig. 3 shows two of these pyrometers which have been in use. It will be noted that several of the fingers are bent over in the manner described above.

From the oven-house, when baked, the carbons are transferred to the cutting, sorting, coring, and finishing departments, a general view of which is given in the illustration at the head of this article. The ends of the carbons are squared and pointed by aid of emery wheels. The core material is forced into the hollow carbons by aid of the hydraulic presses, which can be seen on the right of the illustration.

A very nicely equipped laboratory and test room are provided, as is necessary in an up-to-date works of this description. The carbons are tested under working conditions in various types of arc lamps, precautions being taken to measure the amount of ash, especially in the case where the carbons are to be used in enclosed arc lamps. The rate of consumption of the standard commercial quality of carbon made by this firm, and known by the trade name of "Apostle," is under 0·5" per hour, the current passing being 10 amperes, and the voltage at the carbons 43. The usual sizes are 18 mm. cored and 12 mm. solid. The average ash—or, more correctly, dust—deposited in the globe from one pair of these carbons is about 1½ per cent. by weight, which is a very small quantity. Better quality carbons are also made for enclosed lamps and special purposes. The average annual output of electric light carbons at this works is 12,000,000 feet, and the turnover of battery carbons of all types is 1¾ to 2 millions per annum. The processes used in making the battery carbons are very similar to those employed in the manufacture of arc light carbons. The battery carbons made are principally those suitable for Leclanche and Agglomerate batteries.

A speciality is made of carbons for heavy current work, such as hand feed and automatic projectors, searchlights, lighthouse lamps, etc. Special apparatus has been installed for testing these large-size carbons, which are usually used in a horizontal position.

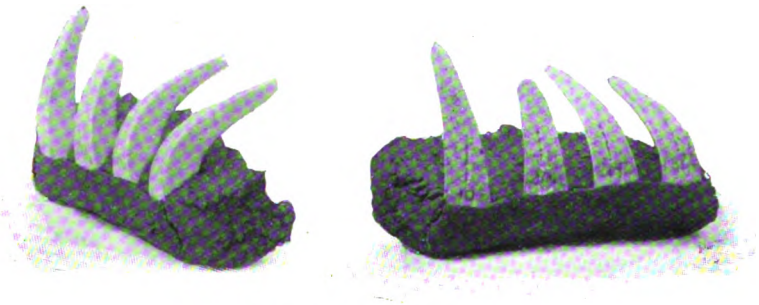

FIG. 3.—PYROMETERS.

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ARRANGEMENT OF MACHINERY IN A MODERN COTTON MILL.

By WM. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

THE planning or arranging of the machinery of a workshop or mill is probably the chief factor, other things being equal, upon which the ultimate success of the concern depends. The economies that can be effected by the most suitable disposition of the machines, tools, etc., are so great that old firms, which have grown up gradually, new machines having been placed, and buildings erected wherever room could be conveniently found, find it pays to spend large sums of money in reorganising and re-arranging their entire works.

In the case of a cotton mill, extensions are seldom made: generally a new mill is built when business is prosperous and there is a great demand for the products; so instead of seeing a series of additional sheds or buildings around the original mill, we find groups of large mills, each complete in itself, with the arrangement of the machinery such that it can produce economically the class of work it has been designed to turn out.

In England, as a rule, a mill is built to spin a given class of yarn, and this it does continuously within very narrow limits; but on the Continent the range of work done in a mill is usually much greater than in England, so that we find expenses to be greater, more hands are required, the machines are more diverse in their setting, and require far greater oversight, both of attendants and of the machines; and, in addition, the machinery is not worked to its full production except in extreme cases.

The planning of a cotton mill is one of the last subjects taught to students in our cotton-spinning classes. It is also a phase of cotton-spinning that has the least attention given to it. This is due to the fact that, beyond a few general principles, the disposition of the machines can be so varied that no two men, working apart from each other, would ever produce similar plans or arrangements. It happens to be a question of individual experience and local conditions. A mere enquiry for a plan of a mill to contain 80,000 spindles to spin 30^3 counts would produce a different set of plans from each machine maker; and even if the ground space to be covered were given, the resulting plans would all be different. In these articles I hope to touch on the various factors that produce such a result, and to point out and illustrate conditions that influence the final arrangement of the machines.

Before a cotton mill can be planned it is necessary to know

1. The ground space at disposal.
2. Whether a storey mill or a shed is required.
3. Most convenient place for loading and unloading.
4. The position of the engine.
5. Number of spindles the mill must contain, or the production necessary per week.
6. The production per machine or spindle of each unit in the mill.
7. The counts of yarn to be spun.
8. The dimensions of each machine that will be placed in the mill.

In addition to these there are a number of other important details that must be settled before a mill plan can be designed—details connected with each set of machines and each process, for instance:—weight of lap, hank sliver, hank roving, speeds of spindles, space of spindles, twists per inch, space occupied by the gearing end of frames, kind of driving, whether open drive or half-twisted belts, width of passages, position of pillars and their distance apart, etc.

A cursory glance at the above headings will be sufficient to explain why the subject

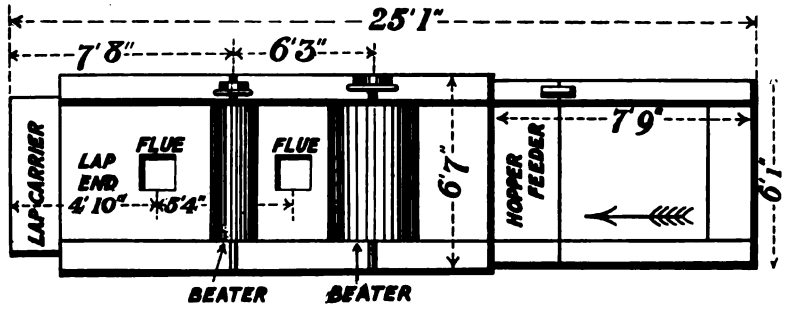

FIG. 1.

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cannot possibly be treated in more than an elementary manner by teachers. The subject is so complicated that only by constant work for a long period will a student be able to thoroughly master this phase of cotton spinning. A good deal of information can be tabulated and used for reference, but there will still remain many problems requiring sound judgment and experience. A study of

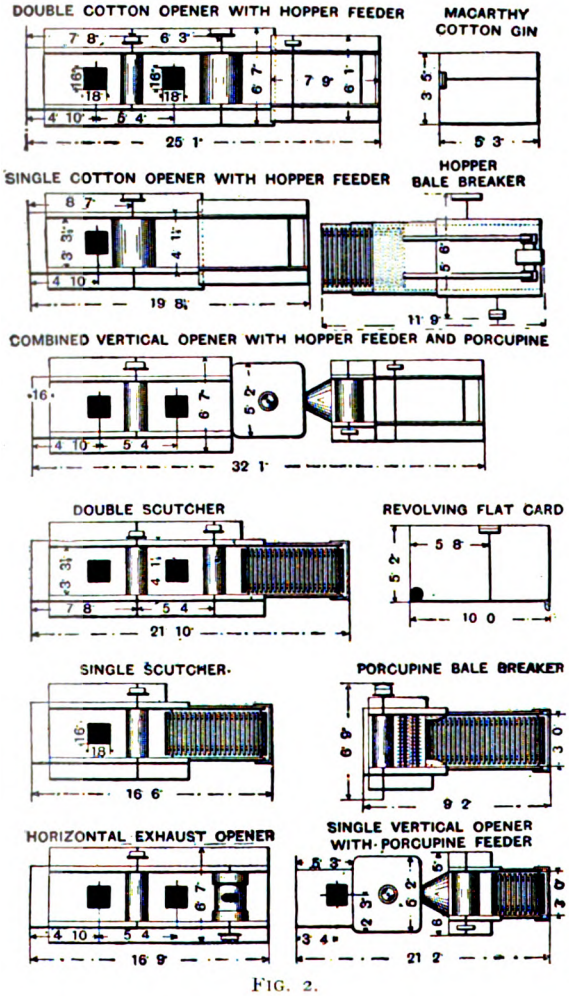
DOUBLE COTTON OPENER WITH HOPPER FEEDER
MACARTHY COTTON GIN
SINGLE COTTON OPENER WITH HOPPER FEEDER
HOPPER BALE BREAKER
COMBINED VERTICAL OPENER WITH HOPPER FEEDER AND PORCUPINE
DOUBLE SCUTCHER
REVOLVING FLAT CARD
SINGLE SCUTCHER
PORCUPINE BALE BREAKER
HORIZONTAL EXHAUST OPENER
SINGLE VERTICAL OPENER WITH PORCUPINE FEEDER

FIG. 2.

typical plans drawn up by experienced firms will do much to help a student in forming a clear idea of how to set about mill planning; I hope to give several plans for this purpose.

A good way to make a beginning in mill planning is for a student to familiarise himself with the plans of the various machines. These plans are usually views of the machines looking down upon them from above, and a sketch of their outlines, with over all dimensions, will enable us to place them in positions relative to other machines so that passages between them are adequate for the workpeople to pass to and fro without danger, and to enable them to do their work without inconvenience.

A specimen sketch plan is given in Fig. 1 of a double cotton opener and hopper feed. The extreme length and width are shown, and the dimensions include covers, brackets, ends of shafts, etc., so that when another machine is placed near to it, the passage between the two will be represented as the distance between the nearest points in either machine. This must be carefully observed in all machine planning, so that as the attendant passes along she must be able to move naturally, and the passage wide enough to prevent any contact of the clothes or body with any part of the machines on either side. The sketch also shows the driving shafts and their distances from one end of the machine; this is necessary so that we may know how to place the machine relatively to the main driving shaft from which the machines derive their power, or where we can most conveniently place the main driving shaft.

Students are strongly advised to draw out to scale a set of machines, after measuring up actual machines if possible, and if not, then a set of machines taken from drawings given in Figs. 2 and 3, which represent the sizes of the machines made by the well-known firm of Dobson and Barlow, Bolton, to whom we are indebted for the loan of the blocks. When scale drawings have been made on thick paper they can be cut out along their outlines and duplicated, so that they lend themselves to be arranged just as conditions require in the rooms of the mill. When students have made themselves familiar with the sizes of the machines that do not vary, such as the scutching room and card room machinery, they will require to know how to get the lengths of the fly frames and spinning machines, for these may be of varying length, according to the number of spindles they contain and the space of the spindles. For instance, the lengths of the fly frames in Fig. 3 will be found by multiplying half the number of spindles by the space of the spindles, and adding 3 feet for the space occupied by the pulleys, frame ends, etc. When a mill plan comes to be actually

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drawn, tables are generally used to obtain lengths, etc., but students would do well to work out for themselves all such lengths, and so have at their command means of proceeding when tables or references are not at hand, such as in examination work, etc.

general knowledge of the chief requirements in order to spin certain counts of yarn. For instance, he ought to be able to draw up a list something like the foregoing, if he should be asked the details for spinning 20's yarn.

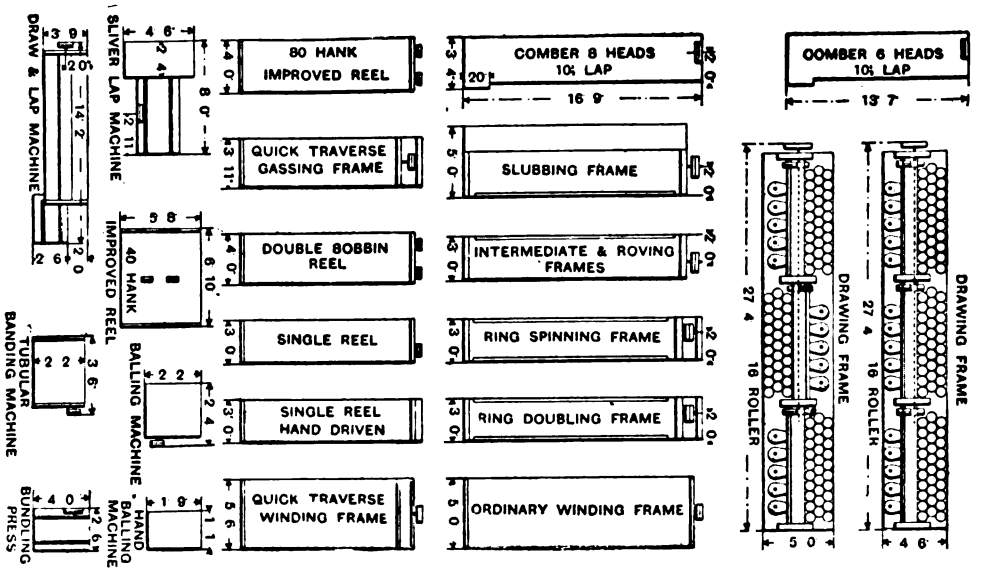

FIG. 3.

Machine.	Hank Roving.	Draft.
Card	·138	100
Draw Frame	·138	6
Slubbing Frame . . .	½	3·6
Intermediate Frame . .	1¾	5·5
Roving Frame . . .	3¼	4·72
Mule	20	6·15

The reader who has reached the stage of mill-planning ought also to have a good

Some of these details can be varied according to experience, but before a mill plan can be settled some such list is a necessity, and the details must be clearly denoted before commencing. Alterations afterwards will lead to differences in number of machines, etc. Students who desire advancement must always be on the alert to make a note of such information as the above, for it is on the possession of these details that a good deal of a man's success depends.

(*To be continued.*)

A series of articles by Mr. SCOTT TAGGART, of which the above is the first, will be published from month to month in TECHNICS. *Arrangements have also been made with Mr. HARRY NISBET, Weaving Master at the Bolton Technical School, to contribute a series of articles on "Special Devices Used in Weaving." The first instalment will be published in the October number.*

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THE MICROSTRUCTURE OF BRASS.

By ARTHUR H. COOTE, F.C.S., of the Ordnance College, Woolwich.

BRASS is an alloy of copper and zinc, which in the proportion of 70% copper and 30% zinc form an alloy approximately of the composition $Cu_3 Zn$ and of constant melting point. There are many varieties of brass, all produced by varying the above proportions, with corresponding alterations in melting point and general properties.

The present article deals with the microstructure of brass of the above composition, free from impurities such as iron, lead, sulphur or oxide of copper, all of which have a very marked influence on the character of the metal and its microstructure.

If an ingot of brass be broken across, it will be seen to consist of a number of interlacing crystals. It is far easier to fracture while hot than when cold, because the eutectic lying between the crystals, having a lower melting point, becomes readily plastic or soft, and allows the crystals to be drawn apart from one another.

If now a section of the ingot be made, polished and etched with nitric acid (sp. gr. 1·42) only for an instant, and then rinsed in running water, the facets of the crystals become visible to the naked eye. They are very large, having crystallised out from the liquid metal as it slowly cooled, and all point towards the interior of the ingot—the last region to solidify. On examination under the microscope they are seen (Fig. 1) to have a feathered appearance, the ends being rounded off. The dark portion represents the eutectic, containing the impurities.

This appearance is always obtained when brass is melted and allowed to cool. It is known to the workman as "burnt brass" by its brittleness, possessing all the properties of ingot brass. This is a somewhat erroneous term. It is really "melted brass." The longer it is kept at this high temperature of fusion, the more oxide of copper ($Cu_2 O$) is produced and dissolved in the brass, thus increasing the dark portions between the feathers, producing an egg-like appearance, and weakening the character of the metal.

If now the ingot be *worked*, *i.e.*, rolled, hammered, punched, etc., it is well known to the practical man that it becomes harder and harder till it can no longer be worked. It must now be *annealed* or softened, when it can be worked until it has become so hard as to require annealing once more, and so on.

Micro-analysis not only reveals what has happened to the metal during hardening and

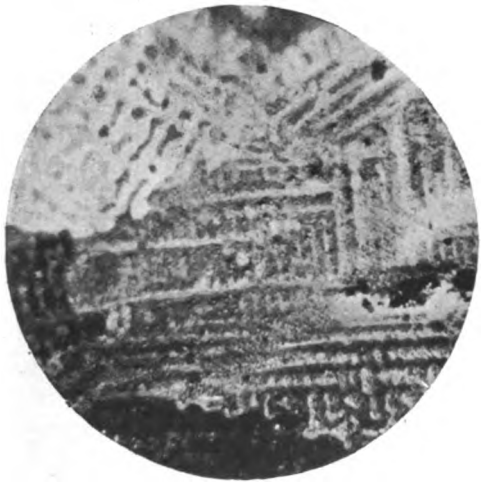

FIG. 1.—CRYSTALLINE STRUCTURE OF INGOT BRASS.
(*Magnification*, 58 *diameters*.)

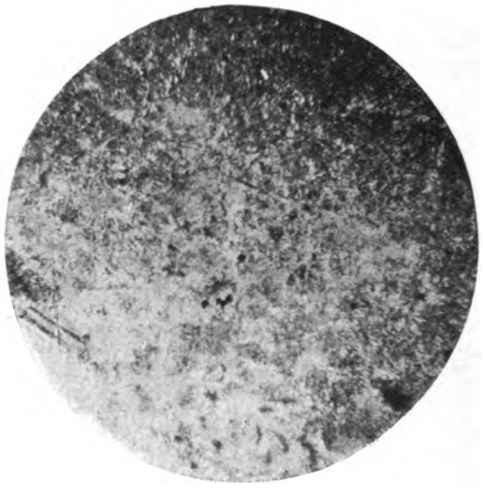

FIG. 2.—INGOT BRASS ROLLED DEAD HARD.
(*Magnification*, 58 *diameters*.)

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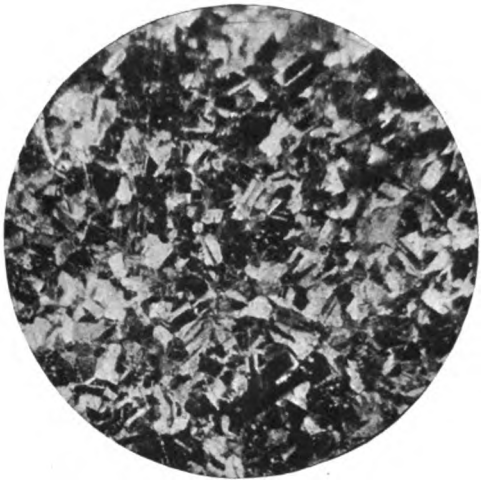

FIG. 3.—BRASS, AFTER HEATING TO 500° C.
(*Magnification*, 58 *diameters.*)

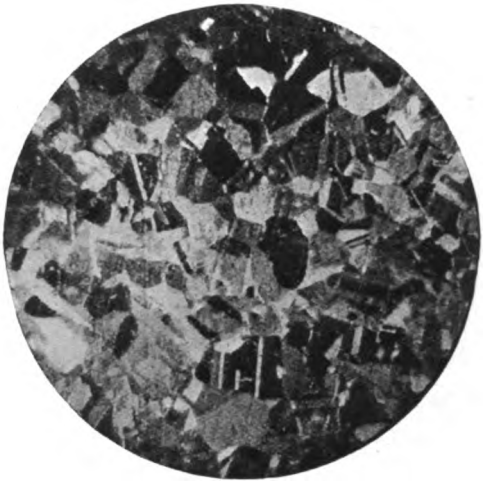

FIG. 4.—BRASS, AFTER HEATING TO 600° C.
(*Magnification*, 58 *diameters.*)

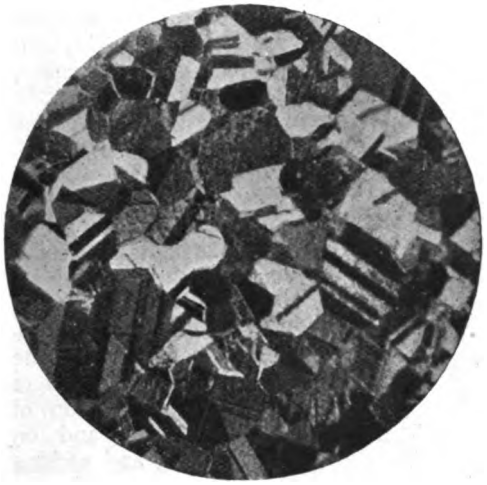

FIG. 5.—BRASS, AFTER HEATING TO 750° C.
(*Magnification*, 58 *diameters.*)

FIG. 6.—BRASS, AFTER HEATING TO 800° C
(*Magnification*, 58 *diameters.*)

annealing, but it also tells the workman that he must take the following precautions:—

(*a*) That in order to obtain a certain standard of *softness*, he must anneal at a fixed temperature.

(*b*) That the annealing oven should be kept at a constant temperature during the time it is in use, and also at a uniform temperature in *all parts* of the oven.

(*c*) That *all* the metal should reach the temperature of the oven.

(*d*) That it should not be too long in reaching this temperature.

The photo-micrographs illustrating this article speak for themselves. They are all of 58 diameters magnification.

Fig. 2 is ingot brass that has been rolled "dead hard." Rolling any annealed brass produces a similar effect. There is little structure to be seen: it is practically a homogeneous metal. I may add that hammering, crushing, punching, or even firing a cartridge in its chamber in a rifle will produce a like effect.

Fig. 3 is this hard brass heated to 500° C. or 930° F. It consists of a large number of small crystals uniform in size. It is still fairly hard.

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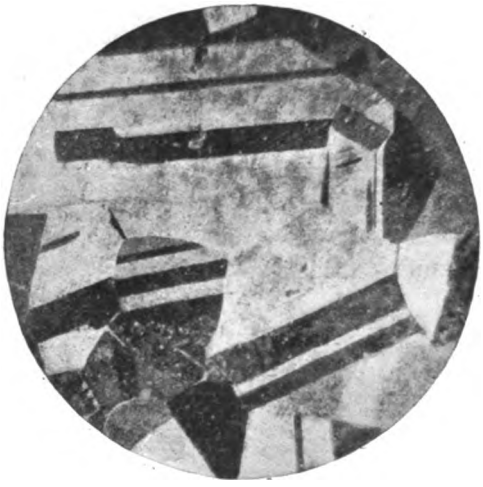

FIG. 7.—BRASS, AFTER HEATING TO 900° C.
(*Magnification*, 58 *diameters.*)

FIG. 8.—BRASS, AFTER HEATING TO 1,000° C.
(*Magnification*, 58 *diameters.*)

Fig. 4 has been heated to 600° C. or 1100° F.
Fig. 5 has been heated to 750° C. or 1380° F.
Fig. 6 has been heated to 800° C. or 1470° F.
Fig. 7 has been heated to 900° C. or 1650° F.
Fig. 8 has been heated to 1000° C. or 1830° F.
Fig. 9 has been heated to 1015° C. or 1860° F.

In Fig. 9 the crystal shape is still preserved, but the character of Fig. 1 is developing. It is in an incipient melted condition.

The principal conclusion to be drawn from this series is, that as the temperature rises, there is a gradual increase in the size of the crystals, and the metal becomes softer and softer: hence the above precaution (*a*).

I have been unable to detect the slightest difference between slowly-cooled and water-cooled brass after heating to the same temperature—confirming workshop experience.

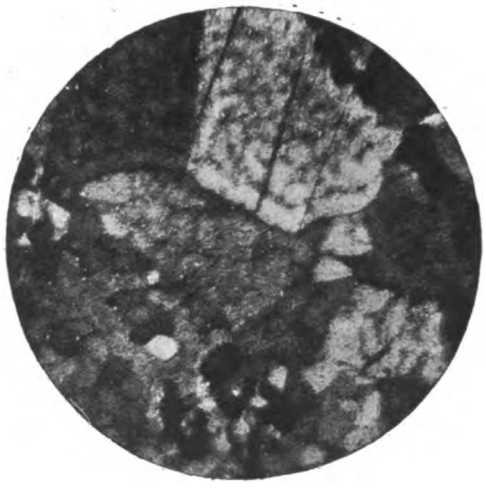

FIG. 9.—BRASS, AFTER HEATING TO 1,015° C.
(*Magnification*, 58 *diameters.*)

Uniformity of results, when the finished article has to resist any considerable strain, is only attained by working according to (*b*).

The best brass, being of uniform hardness, is that with the most uniform size of crystals: hence precaution (*c*).

The longer the metal is in the furnace, the more of the lower oxide of copper (Cu_2O) is produced; this, dissolving in the brass, renders it brittle, hence precaution (*d*).

Two questions now present themselves and can, I think, be satisfactorily answered.

1. *Why should the temperature at which the brass is annealed determine the size of the crystal developed?*

That this is so is best seen by melting a piece of brass at one end in an oxy-hydrogen flame, keeping the other end cold. Here there is gradation of temperature, and on polishing and etching a perfect gradation in size of crystal is seen. I have made a composite photograph of such a piece, but as it measures 4 feet 6 inches in length it is unsuitable for reproduction in this article.

The explanation is that brass when heated becomes plastic: the higher the temperature, the greater the plasticity, till melting occurs. It is, I think, self-evident that low plastic brass would, on cooling, set into a mass of small crystals; and the more plastic the metal is, the more easily is there molecular rearrangement, and the larger are the crystals. The

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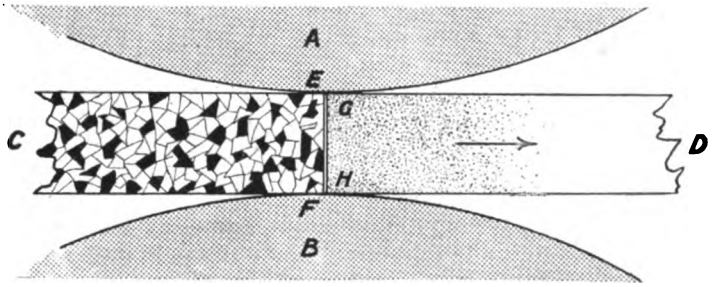

FIG. 10.—TO ILLUSTRATE THE DESTRUCTION OF CRYSTALLINE CHARACTER OF BRASS, DUE TO ROLLING.

larger the crystal the softer the metal, as there is less friction under a moving stress among the large crystals, than among many small ones.

2. *How is it that "working" brass destroys its crystalline character?*

Here again the explanation is that *rolling*, for instance, has the same molecular effect as raising the temperature. So does punching, etc.

Both conditions consist in the performance of work on the molecule. Hence during this expenditure of energy the metal becomes *plastic.*

That it does become plastic is proved by the fact that it alters its shape. In the case of *punching* "the flow of the crystal" is very evident.

But why does the crystalline character disappear if this is the case?

Reference to the diagram (Fig. 10) makes the explanation quite clear.

A and B are transverse sections of two rollers: C E D is a piece of soft brass passing between them. E F is the common normal to the rollers. At this plane we have the region of maximum pressure. The thickness of the brass from C to E is slightly greater than from E to D, and from E to D it is of uniform thickness.

At the plane G H, say $\frac{1}{100}$ inch from E F, there is a region of no pressure.

The brass takes but a very small fraction of a second in passing from a thin plane of maximum pressure and greatest plasticity to a region of no pressure and solidity, the pressure being removed instantaneously.

The crystals present in the part C to E are therefore divided into a large number of planes, each successively plastic and then solid. The portions of crystals in the same plane being treated simultaneously fuse together, and as a result there is no possibility of crystallisation. The crystals disappear, and the metal becomes homogeneous. The interior of the metal is also in a state of strain, and being structureless is hard in character.

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THEORY OF STRUCTURAL DESIGN.

PART IX.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

STRENGTH OF PILLARS.

CAST-IRON columns, steel stanchions, wrought-iron struts, wooden pillars, and brick piers, though they vary much in external appearance, in their method of construction, and in their constituent materials, nevertheless afford particular examples of the one general principle of longitudinal compression of long members. It is, therefore, desirable to put them all under some distinctive general name. Our choice of such a general term is admittedly limited to pillar or column. According to Chambers' Dictionary, a column is a long *round* body used to support a building, while a pillar is defined as a support, differing from a column since it is not necessarily cylindrical. The word pillar would thus appear to be the more comprehensive, and will be adopted hereafter as including all the rest.

Pillars are technically known as long, short, or medium; not by reason of their lengths as compared one with another, but by a comparison of the ratios which are obtained by dividing the length of each pillar by its least diameter. Thus the length may be expressed as ten, twenty, or forty diameters. This classification is a very useful one, but it is far from perfect. For instance, in the technical sense, A (Fig. 41) is a long pillar, while B (which is twice as long as A) is a short pillar.

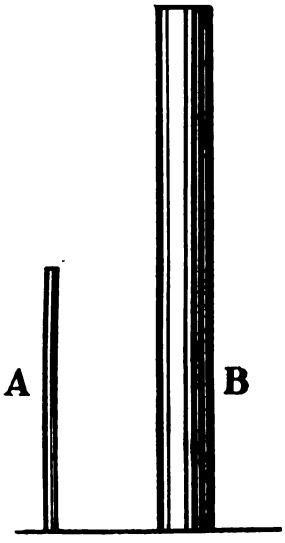

FIG. 41.

If a pillar, of which the length does not greatly exceed its least diameter, be tested to destruction, the exact manner of failure will depend upon the nature of the material. Lead will flatten out, cast iron may develop diagonal planes of fracture, and sandstone may be crushed till it splits into innumerable particles.

In practice, if we have a very long pillar of slender diameter, even though its ends be flat and well fixed, it is impossible to guarantee that the geometrical axis of that pillar is absolutely vertical and also of mathematical straightness; and it is also very improbable that the centres of pressure at the top and bottom are exactly coincident with the geometrical axis of the pillar.

In practice, there must therefore always be some bending tendency in long pillars. This tendency may be slight, and even in some instances immeasurably minute, but it is always present.

If the pillar is very long and the load excessive, failure will take place by bending. In this case, destruction will be preceded by increasing lateral deflection or camber.

We see then that short pillars fail by direct crushing, while long pillars fail by bending, and it follows that medium pillars will fail, partly by bending and partly by crushing.

There is no definite line of demarcation between these three classes. They glide imperceptibly one into the other; in fact, there is probably some bending in the shortest pillar, and indubitably some crushing in the longest.

In combating the student's misconception that pillars fail by gyration in some mysterious manner, it is perhaps desirable to enumerate further causes of bending or increase of curvature, and want of initial straightness in built-up mild steel pillars or stanchions.

(*a*) The steel may not be of uniform elasticity.

(*b*) Every built-up stanchion is rivetted together when laid on its side in the erecting shop; and the temporary timber supports or bearings during the rivetting process may not be in alignment.

(*c*) The supports may be too far apart, and the stanchion may be rivetted up in a deflected or cambered position.

(*d*) Accidents during transit and loading may affect the straightness of a stanchion, particularly if it is very long and slender.

(*e*) No engineer dare guarantee that the

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cap plate and the base plate lie in exactly parallel planes.

(*f*) Although the specification may say that the cap plate and base plate shall be truly perpendicular to the axis of the stanchion, we all know that the purchasers only get a more or less close approximation to this ideal condition.

(*g*) The stanchion will most probably take some of its load from side brackets, and this eccentricity of loading will produce bending.

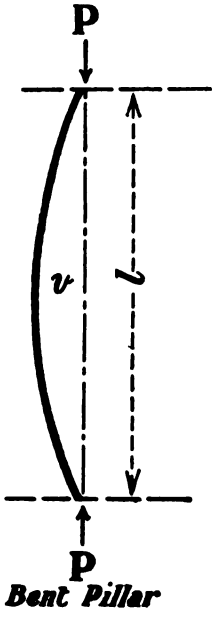

FIG. 42.

(*h*) The load on the top of the stanchion may bear on the edge of the cap plate.

(*i*) The foundation block cannot be made absolutely level and smooth.

(*j*) The subsoil under the foundation block may not possess the same bearing power at every part.

These and many other factors all help to give force to the statements that absolutely straight, vertical, centrally loaded stanchions are ideal cases unknown in practice; and all stanchions have a tendency to bend.

I purpose showing how the standard formulæ, which take into account the bending stresses in addition to the direct compressive stress, are obtained; and afterwards to give some labour-saving rules for finding the radii of equivalence and the safe working loads for mild steel pillars.

Let P = the load in tons.

„ A = cross-sectional area in sq. ins.

„ I = the second moment of the area, *i.e.*, the geometrical moment of inertia (in inches^4).

„ f_b = the maximum stress on extreme fibres due to bending (in tons per square inch).

„ y = the distance between extreme fibres and the neutral axis (in inches).

„ l = length of pillar in inches.

„ v = the greatest lateral deflection of the axis of the pillar (in inches).

The compressive stress due to the uniform distribution of the load over the cross-sectional area

$$= \frac{P}{A} = f_c.$$

The bending moment at middle section of pillar = Pv (see Fig. 42).

The moment of resistance = $I\frac{f_b}{y}$.

$$Pv = I\frac{f_b}{y};$$

$$\therefore \quad \frac{y\,P\,v}{I} = f_b.$$

In a symmetrical section $y = \frac{d}{2}$, where d = diameter of the stanchion in the direction in which bending will take place;

$$\therefore \quad \frac{Pvd}{2I} = f_b. \quad \text{(Eqn. XXXII.)}$$

Let r = the radius of equivalence (*i.e.*, the least radius of gyration in inches).

Then $I = Ar^2$, and by substituting in Equation XXXII. we have

$$f_b = \frac{P}{A} \cdot \frac{vd}{2r^2}.$$

It is shown in advanced text-books, and it may be verified by simple experiment, that the greatest deflection of a beam or pillar, consistent with unimpaired elasticity, is directly proportional to the square of the length and inversely proportional to the depth of the beam, or the least diameter of the pillar.

In other words, within the elastic limit of the material the deflection of a beam or pillar may be represented by an equation of the form

$$v = k\frac{l^2}{d},$$

where k is a constant which may be found by theory and verified by experiment. By substituting $k\frac{l^2}{d}$ for v, we now have

$$f_b = \frac{P}{A} \cdot \frac{d}{2r^2} \cdot \frac{kl^2}{d}$$

$$= \frac{P}{A} \cdot \frac{k}{2} \cdot \frac{l^2}{r^2}.$$

Let $\frac{k}{2}$ be replaced by the equivalent constant a, then

$$f_b = \frac{P}{A} a \left(\frac{l}{r}\right)^2. \quad \text{(Eqn. XXXIII.)}$$

The total stress f on the pillar, on the concave side, equals the stress due to the

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uniform distribution of the load, plus the extra stress due to bending.

On concave side $f = f_c + f_b$. (Eqn. XXXIII.)

On convex side $f = f_c - f_b$, since f_c is compression, while $-f_b$ represents tension.

Or, more briefly, $f = f_c \pm f_b$.

Let f_r = the greatest stress which the material can stand with unimpaired elasticity and without injury. This stress is, of course, much lower than the ultimate crushing strength of the material. For mild steel f_r may be taken at 40,000 lbs. per square inch; say, 17·8 (or approximately 18) tons per square inch.

Putting f at its maximum value f_r, and putting in the values of f_c and f_b, we have

$$f_r = \frac{P}{A} + \frac{P}{A} a \left(\frac{l}{r}\right)^2$$

Or in words this means that

$$f_r = \text{once } \frac{P}{A} + a\left(\frac{l}{r}\right)^2 \text{ times } \frac{P}{A},$$

$$\therefore \quad f_r = \frac{P}{A}\left[1 + a\left(\frac{l}{r}\right)^2\right]$$

On dividing both sides of this equation by $1 + a\left(\frac{l}{r}\right)^2$ and multiplying both sides by A, we have

$$P = \frac{f_r A}{1 + a\left(\frac{l}{r}\right)^2} \quad . \quad \text{(Eqn. XXXIV.)}$$

For mild steel pillars with caps and bases flat and well bedded $a = \frac{1}{18000}$, while f_r, as before stated, = 18.

Equation XXXIV. is spoken of as the equation to the crippling load on the pillar. It is more truly the greatest load consistent with unimpaired elasticity. It would represent the crippling, buckling, crumpling, or wrecking load if f_r were perhaps about 20 tons instead of about 18; for although we say that the ultimate compressive strength of mild steel is about 30 tons per square inch, the material would suffer irreparable injury by pressures in excess of the elastic limit. These pressures would be accompanied by deflections of so serious a nature that the bending moments would be increased; and the final collapse might be sudden and calamitous.

(To be continued.)

THE VACUUM AUTOMATIC BRAKE.

By ARCHIBALD WILLIAMS.

THE brake most extensively used on the passenger rolling-stock of Great Britain and Ireland is that known as the "vacuum automatic." Its name implies (*a*) that the force employed to apply the brake shoes to the wheels is due to the pressure of the atmosphere acting against an artificially produced vacuum; (*b*) that, as in the case of the compressed air brake, the normal tendency of the braking gear is positive, and will assert itself in the event of a failure of the exhausting apparatus through the accidental parting of a train. The principles and mechanism of this brake are at once so simple and effective that a short description will doubtless interest those readers of TECHNICS who at present are not conversant with them.

Fig. 1 shows the various parts of the apparatus. For the sake of simplicity, the brake levers, shoes, etc., which merit no special notice, have been omitted. To the left is the *combination ejector*, which consists of two ejectors known as the "large" and the "small," the latter being placed within the former. The small one is worked continuously, to counteract any leakage in the pipes, and is controlled by a small screw steam-valve, adjustable to give the required vacuum. When the driver's handle is in its central or "running" position, this small ejector alone acts; but on the handle being turned into a vertical position, the larger ejector also commences to work. The action of both ejectors is the same: steam is blown through the ejector barrel at a great velocity, withdrawing the air from the train-pipe and cylinders, and carrying it along the exhaust pipe into the chimney of the locomotive.

The train-pipe extends from end to end of the train, and bridges the intervals between

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carriages by means of flexible connections each containing a *universal coupling*. The latter is simplicity itself. To engage it, the bottom horn of each half (see Fig. 2) is passed behind its fellow, and on the hose being lowered the top horn of one half falls into a slot in the other. The weight of the hose and the pressure of the atmosphere squeeze the rubber-lined faces of the coupling together so as to form an air-tight joint. To detach the parts, the porter has merely to lift them straight up, when the top horn comes out of its slot and leaves them free of one another.

Under each carriage is suspended, on two

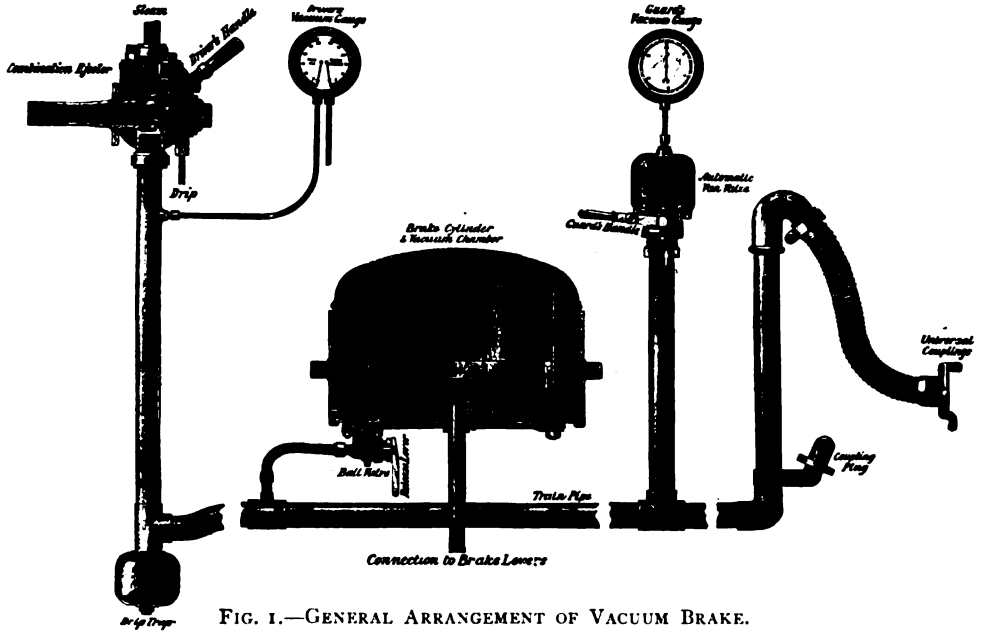

FIG. 1.—GENERAL ARRANGEMENT OF VACUUM BRAKE.

trunnions, a *brake cylinder and vacuum chamber*, connected to the train-pipe by a short length of flexible hose. Fig. 3 shows this part of the apparatus in section, as it appears when the brake is on and when it is off. The cylinder opens at the top into the larger vacuum chamber surrounding it, but at the bottom is closed by a cover provided with a gland for the piston-rod to work through. The piston itself is kept air-tight by a rubber ring, which, when the piston moves, rolls between it and the cylinder, making a perfect packing without friction.

The most ingenious feature of the Vacuum Automatic Brake is the ball-valve arrangement, which enables the driver to exhaust air from both sides of the piston in each cylinder, but prevents the admission of air to the top side when the vacuum in the train-pipe is destroyed. The action of the cylinder will be easily understood after consulting the diagrams: the air is drawn out through the train-pipe from the bottom of the piston *direct*, and from the top by passing the ball. So long as the pressure on the under side of the piston is no greater than that on the upper side, the ball is loose on its seat, and the air can be exhausted from both sides equally. The piston and piston-rod then fall to the bottom of the cylinder by gravity, and the brake is "off." When air is admitted to the train-pipe the ball-valve keeps the vacuum above the piston unbroken, and the piston is driven upwards with a force proportionate to the difference between the air-pressures on its two faces. For instance: if 10 inches is indicated in the train-pipe and 20 inches in the vacuum chamber (by the driver's double vacuum gauge), the brake is applied with a pressure of 10 inches, or about half its full pressure.

Each ball-valve is fitted with a release lever for the purpose of withdrawing the ball from its seat when the brake must be released by hand. The spindle worked by the lever to move the ball is made air-tight by a small diaphragm, the pressure on which, when a vacuum is created, pulls in the spindle and allows the ball to go freely to its seat.

The guard has in his van a valve which, on a handle being depressed, admits air to the train-pipe and applies the brake throughout the train, which it will stop even if the

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engine remain under full steam. This valve is also opened automatically when the driver applies the brake suddenly, so as to increase the rapidity of its action still further. Above the valve is a dome-shaped chamber, closed at the bottom by a rubber diaphragm connected to the valve by a bolt with a small hole through its stem. The chamber is exhausted through this hole, when a vacuum is created in the train-pipe. If a gradual application is made, the vacuum in the chamber is destroyed as quickly as in the pipe; but when the brake is applied suddenly the vacuum beneath the valve is destroyed much more quickly than in the chamber, with the result that the pressure of the atmosphere on the diaphragm lifts the valve, which remains open until the vacuum is destroyed in the chamber through the small hole, when it closes by gravity.

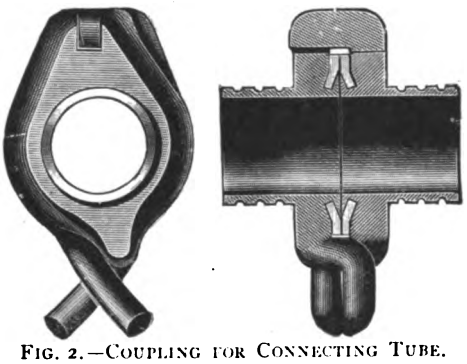

FIG. 2.—COUPLING FOR CONNECTING TUBE.

The driver is instructed to make his station stops by a destruction of 5 to 10 inches of vacuum, which should be re-created slowly as the train comes to rest. By having the vacuum nearly restored at the end of the stop, "jerking" is prevented, and the brake is released without the use of the large ejector.

While the train is in use the coupling at the rear end must be placed on its plug, otherwise a vacuum could not be produced in the pipe.

At present sixty British railways use the Vacuum Automatic, seventeen the Westinghouse automatic. The former brake is fitted to 13,647 engines, 55,987 carriages; the latter to 3,556 engines, 22,083 carriages.

Among the advantages claimed for the vacuum brake are:—

1. Its quick action; the air flows through the train-pipe at ten miles an hour.

2. Economy in steam; an ejector uses less steam than a pump.

3. It can be applied any number of times in rapid succession without diminishing its working capacity, which is always retained, the vacuum in the upper part of the cylinder never being destroyed.

4. Its simplicity.

5. Its latitude of control. The pressure on the blocks can be increased or decreased at pleasure, without removing the blocks from the wheels.

6. The absence of frictional surfaces—the piston being packed with a rolling ring, and the valve being a rolling ball. Therefore no lubrication is required, and the brakes are not affected by frost or cold.

7. Its trustworthiness. The Board of Trade returns, covering the six years 1894—1899, show but one failure in every 305,435 miles run.

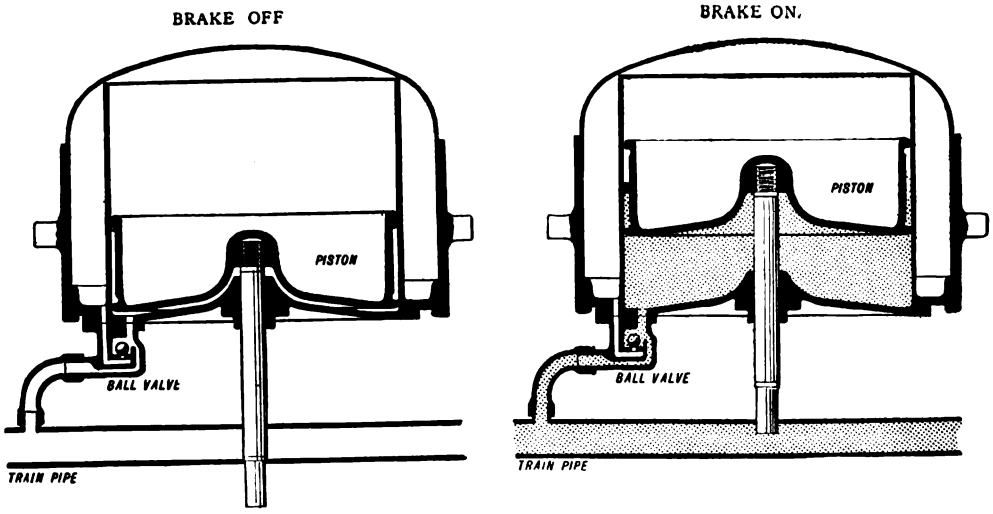

FIG. 3 —TO ILLUSTRATE THE ACTION OF THE BRAKE CYLINDER AND VACUUM CHAMBER.

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During July, 1889, some interesting experiments were made with the brake on the Manchester, Sheffield, and Lincolnshire Railway, and in the workshops of the manufacturers, Messrs. Gresham and Craven, at Manchester. In the first case, a train, consisting of one engine and tender and forty carriages, was run over a practically level stretch of line. Its total weight was $573\frac{2}{3}$ tons, of which 423 tons represented braked vehicles. The first and second stops were made at a speed of thirty-two miles an hour, in 12 seconds from the time of the application of the brake; distance travelled, 342 feet. The train was then arranged for a slip stop. The slipped portion consisted of the last twenty-two carriages, weighing $268\frac{3}{5}$ tons ($187\frac{2}{3}$ tons braked). The speed was thirty-two miles an hour, and 12 seconds elapsed between the slip and the moment of rest; distance run, 240 feet. The two parts of the train stopped within 20 feet of one another.

The workshop tests, made to establish the rapidity of action in applying the brake-blocks to the wheels, showed that on a train of fifty carriages the times occupied after the movement of the driver's lever were: to affect—

The 10th carriage, $\frac{7}{10}$ seconds,
„ 20th „ $1\frac{1}{2}$ „
„ 30th „ $2\frac{1}{4}$ „
„ 40th „ 3 „
„ 50th „ $3\frac{1}{2}$ „

It should be added that the steam used for the ejectors was supplied from a stationary boiler, 300 feet distant.

The Vacuum Automatic Brake is an English invention, being largely due to the ingenuity of Mr. James Gresham, M.I.Mech.E.

In conclusion, the writer has to thank the Vacuum Brake Company, 32, Queen Victoria Street, for placing full information at his disposal, and also for the means of illustrating this short account.

REVIEWS.

Electricity and Matter. By J. J. Thomson, D.Sc., LL.D., Ph.D., F.R.S. pp. 162, with diagrams (Westminster: Archibald Constable & Co., Ltd., 1904.) Price 5s. net.

A book on a comparatively new branch of science, written by one of the foremost pioneers in this branch, is sure to be interesting and instructive. Professor Thomson's is perhaps one of the most interesting books written in recent years. It deals with the latest developments of the Electro-Magnetic Theory, which was crudely formulated by Faraday, developed on a mathematical basis by Maxwell, and confirmed experimentally by Hertz and Lodge. Fascinating as are many scientific theories, there is none which can surpass the Electro-Magnetic Theory, which brings within our knowledge the properties of the ether, a medium imperceptible by the unaided senses; which links together phenomena so diverse as the propagation of light and the electrification of a piece of amber by rubbing; and which has led to inventions so remarkable as that of wireless telegraphy. Maxwell, when Cavendish Professor of Physics at Cambridge, predicted that the nature of electricity would be finally determined from vacuum tube experiments. This prediction strongly impressed his successor, Professor J. J. Thomson, with the result that for many years the Cavendish Laboratory has been recognised all over the world as a centre of research connected with the remote but fundamental properties of electricity. *Electricity and Matter* is a revised version of a series of lectures delivered by the author at Yale University in May, 1903; the subject discussed is the bearing of recent advances in electrical science on our views of the constitution of matter and the nature of electricity. The first chapter is devoted to the representation of the electric field by lines of force; Professor Thomson adopts Faraday's idea that lines of force (or, more correctly, Faraday tubes) are not mere geometrical devices, like meridians of latitude; but that they are real *things*, possessing many of the properties of matter, although they are imponderable and incapable of being directly observed by the senses. In the second chapter, on electrical and bound mass, it is shown that Faraday tubes, when moving perpendicular to their length, possess inertia; and as a charged body necessarily carries the Faraday tubes ending on it from place to place in its motion, it follows that the inertia of matter may be wholly or partially due to Faraday tubes. The third chapter is devoted to the study of Röntgen rays and light: light waves are supposed to consist of pulses trans-

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mitted along Faraday tubes, just as a jerk on one end of a stretched string will cause a displacement which is transmitted with a definite velocity to the other end of the string. The atomic structure of electricity is discussed in Chapter iv.; according to Professor Thomson, negative electrification consists of an assemblage of corpuscles (or electrons), each possessing a mass equal to about one one-thousandth part of the mass of a hydrogen atom; while the carriers of positive electricity are atomic in size. Thus an atom consists of a collection of large positively charged particles, together with the small negatively charged electrons. The constitution of the atom is discussed in Chapter V.: this is perhaps the most fascinating chapter of the book, comprising, as it does, many suggestions which go far to explain chemical and physical phenomena, such as the spectra of the elements, the periodic law, etc. etc. The last chapter deals with radio-activity. On the whole, it must be confessed that the views advocated by Professor Thomson are in many respects speculative; but their value is best gauged, not by the extent to which their conformity to nature has been proved, but by their suggestiveness in indicating lines of research which will indubitably lead us to a better knowledge of the properties of matter and electricity.

Radio-activity: an Elementary Treatise from the Standpoint of the Disintegration Theory. By Fredk. Soddy, M.A. pp. xii. + 214, with forty illustrations. (London: The Electrician Printing and Publishing Co., Ltd., 1904.) Price 6s. 6d. net.

Association with the researches of Professor Rutherford has fitted Mr. Soddy in the best possible manner for the task of expounding the disintegration theory of radium and its properties. Mr. Soddy's book is clearly and succintly written: its illustrations fulfil the purpose for which they were designed (*viz.*: to explain the reasoning used in the text), and a most elaborate and useful index has been added at the end. The subject is treated in a thoroughly scientific manner, without the use of much mathematics; this should prove of great advantage to those who wish to obtain accurate information without wading through long and tedious analytical investigations. In reading Mr. Soddy's book, however, one cannot fail to be struck by the air of confidence with which not only the main conclusions, but also many of the minor assumptions of the disintegration theory are stated. It were unwise in the extreme to refuse attention to the conclusions which Professor Rutherford and his students have arrived at; and several of these have been verified in a manner which, to say the least, is truly remarkable. But the study of radio-activity is as yet young in years, and it may possibly be found that many phenomena, which at present appear to admit of no explanation outside the disintegration theory, can be better explained by some extension or modification of that theory. In writing this, we fully realise that the disintegration theory is the best put forward so far; but we would urge that it is advisable, at present, not to be too dogmatic in the statement of conclusions. Lord Kelvin has recently championed the idea that the heat emitted by radium is really due to the absorption of some form of radiation to which ordinary matter is transparent. An opinion from so high an authority must be accepted with profound respect; but nevertheless it seems to be quite insufficient to explain the greater number of phenomena connected with radio-activity. For instance, it has been proved that the greater part of the heating effect is due, not to the radium itself, but to the emanations this gives off. If we modify the conclusion reached by Lord Kelvin, so far as to say that the emanation absorbs the unknown radiations, we are still far from being out of our difficulties. In the first place, the emanation (or the product of the emanation which clings to solid bodies brought into contact with it) loses its heating capacity as time progresses; we must therefore assume that the emanation or its product becomes more and more transparent as time elapses. Then Sir William Ramsay and Mr. Soddy have found that the emanation has many of the properties of an ordinary gas, its volume being diminished by pressure, and liquefaction occurring at a sufficiently low temperature. Further, Dr. Collie has found that the emanation has a distinct spectrum, differing from that of radium; while Sir William Ramsay and Mr. Soddy have shown that at a certain stage the emanation or its products give a transient spectrum of helium. Thus, in spite of Lord Kelvin's opinion, it may well be maintained that the ordinary theories current ten years ago are totally insufficient to explain the main phenomena of radio-activity, and we therefore thankfully accept Professor Rutherford's disintegration theory, not perhaps with that feeling of security which we entertain for such a theory as that of the conservation of energy, but at least with an appreciation of its present helpfulness. Professor Rutherford's theory may need modification—there are few theories which can claim immunity from change—with the advent of new discoveries; but at present it appears to fit in well with the facts of the case; and if it is not quite consonant with our previous scientific convictions, we must be ready to abandon these, as our fathers abandoned the theory of caloric and other outworn physical explanations.

Elementary Treatise on Electricity and Magnetism. By G. Carey Foster, F.R.S., and Alfred W. A. Porter, B.Sc. Founded on Joubert's "Traité Elémentaire d'Electricité." Second Edition. pp. xix. + 568, with 374 illustrations. (London: Longmans, Green & Co., 1903.) Price 10s. 6d. net.

Those who wish to obtain an accurate and comprehensive knowledge of electricity and magnetism cannot do better than to procure this book. The high scientific attainments of the authors suffice to guarantee trustworthiness for the book; and one has not to read far to fully appreciate the impressive yet simple style of writing employed. Every law of any great importance in electricity and magnetism is established and discussed; many important

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conclusions, which are quietly assumed in more elementary works, and proved by the aid of difficult mathematics in standard treatises such as that of Maxwell, are here deduced by the aid of ordinary mathematical reasoning. Exception may, however, be taken to one innovation introduced by the authors: instead of defining the unit magnet pole in the usual way, and subsequently deducing the value of the magnetic moment of a magnet, the authors start with the definition of a magnet of unit magnetic moment. For this innovation it may be said that a single magnetic pole cannot be experimentally realised, any magnet having at least two poles. But when due weight has been given to this consideration, it may still be maintained that the definition of a unit pole is easier to grasp than that of a magnet of unit magnetic moment, and that the usefulness of fundamental units depends, not so much on their representing physical entities, as in the ease with which quantitative relations between physical phenomena can be expressed by their aid.

Cotton Spinning: Its Developments, Principles, and Practice. By Richard Marsden, Mem. Soc. Arts. pp. xvi. + 361, with 101 illustrations. (London: Geo. Bell & Sons, 1903.) Price 6s. 6d.

That this book is well known to, and highly appreciated by, students of cotton spinning, is proved by the fact that it is now reprinted for the fifth time since its original publication in 1884. An ambitious young cotton spinner, who looks forward to the day when he will occupy a position of trust, can scarcely do better than commence the study of his craft from Mr. Marsden's book.

Silk Dyeing, Printing, and Finishing. By George H. Hurst, F.C.S. pp. viii. + 226, with 20 illustrations and xi. plates of coloured silk patterns. (London: Geo. Bell & Sons, 1892.) Price 7s. 6d. net.

This excellent handbook belongs to the same series as the one on cotton spinning just mentioned, the series being edited by Sir H. Trueman Wood. Every care has been taken to present the fundamental principles of silk-dyeing to the student in a simple yet accurate manner; details of the machinery used are also dealt with. This book is to be strongly recommended to students.

Principles of Wool Combing. By Howard Priestman. pp. xii. + 272, with 80 illustrations. (London: Geo. Bell & Sons, 1904.)

The operation of wool-combing is apparently simple, while yet it involves a knowledge of many physical and chemical laws. Mr. Priestman's book is well up to date. After discussing the problems presented in wool combing, the principal machines to-day used in this operation are described. Every detail of the process is thus rendered clear; methods of performing calculations are explained and used where necessary.

Preliminary Practical Mathematics. By S. G. Starling, B.Sc., A.R.C.Sc., and F. C. Clarke, B.Sc., A.R.C.Sc. pp. viii. + 168. (London: Edward Arnold, 1904.) Price 1s. 6d.

The average technical student soon feels the necessity for a knowledge of elementary mathematics when he joins a workshop or laboratory class; this book has been written to supply an introductory knowledge of the kind required. Though the scope of the book is somewhat limited, it will, on that account, prove of no less use to those for whom it has been written; it contains just that amount of mathematics which is indispensable to all students who deal with calculable magnitudes. It is well written, the reasoning is clear, and numerous exercises (with answers) are given.

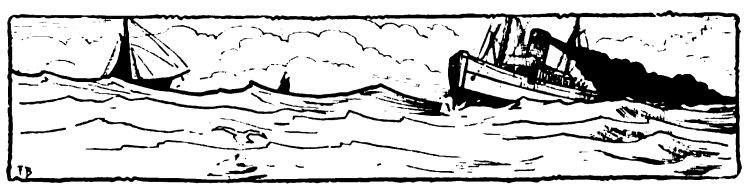
The Elements of Plane Trigonometry. By R. Lachlan, Sc.D., and W. C. Fletcher, M.A. pp. viii. + 164. (London: Edward Arnold, 1904.) Price 2s.

This slender book should be appreciated by students, who will find in it a great part of the plane trigonometry which they will require in their mechanical and physical studies, treated in a manner which renders it clear and interesting. An excellent feature is the use of graphs of the various trigonometrical functions. The student who works through the book will be carried as far as De Moivre's theorem, and attain some knowledge of hyperbolic functions. Numerous exercises (with answers) are given.

Leather Working. Edited by Paul N. Hasluck. p. 160, with 152 illustrations. (London: Cassell & Co., 1904.) Price 1s.

Harness Making. Edited by Paul N. Hasluck. pp. 160, with 197 illustrations. (London: Cassell & Co., 1904.) Price 1s.

These two useful and attractively got-up books should prove useful to those engaged in the leather industries..



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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

GEOMETRY.—Construct an equilateral triangle, having given the distances of its angular points from a given fixed point.

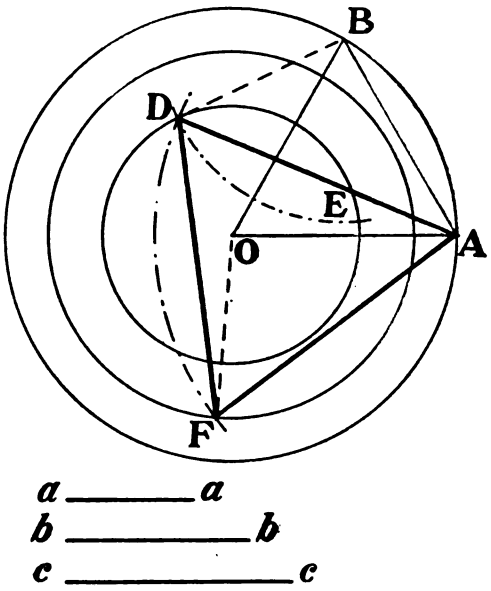

FIG. 1.—(GEOMETRY.)

Let *aa*, *bb*, *cc* (Fig. 1) be the given distances of the angular points of the equilateral triangle from the fixed point O. With the lengths *aa*, *bb*, *cc* as radii, describe circles about O as centre. Draw any radius OA to the outer circle, and on OA construct the equilateral triangle OBA. With B as centre, and *bb* as radius, describe an arc of a circle cutting the circle of radius *aa* in the points D and E. With A as centre, and AD as radius, describe the arc DF cutting the circle of radius *bb* in F. Join AD, DF, FA; then ADF is an equilateral triangle satisfying the given conditions. Another equilateral triangle can generally be found to satisfy the given conditions by describing an arc with A as centre, and radius AE, and then proceeding as before. The two constructions give triangles, such that, in one the point O is within, while in the other the point O is without the required equilateral triangle.

The angular points of the triangle DAF are obviously at the required distances from the point O; it therefore merely remains to be proved that DAF is equilateral. The sides AD and AF are equal, by construction. It is only necessary, therefore, to prove that one angle of the triangle DAF is equal to 60°; *e.g.*, to prove that $\angle FAD = \angle OAB$. To prove this, join BD, OF. Then in the two triangles AFO, ADB,

$$AF = AD,$$
$$AO = AB,$$
$$OF = bb = BD.$$

Therefore the triangles AFO, ADB are equal in all respects, and $\angle FAO = \angle DAB$. To both these add the angle OAD; then $\angle FAD = \angle OAD$.

A similar proof may be used in connection with the equilateral triangle to which the point O is external.

WAVE THEORY.—According to the wave theory of light, the illumination at any given point of a screen is due to the resultant of the vibrations arriving there from all points of the source. Why is it that the light waves from a gas flame (which consists of numberless independent glowing carbon particles) do not neutralise each other's effects at any point, and thus produce darkness?

The answer to this query is fairly obvious, if we consider another problem based on similar physical principles. Why is it that there is not silence in a boiler-maker's shop, due to the incessant hammering of a great number of men? Obviously the resultant vibration at any given spot might, *for an instant*, be equal to zero, if the vibrations arriving there were such as to neutralise each other's effects; and if the vibrations continued with the same amplitudes and relative phase-differences, there would be permanent silence at the spot in question, though elsewhere there would be enhanced sound. But, as a matter of fact, the waves emitted by the source (whether it be the hammering in the workshop, or the vibrations of the carbon particles) are not regular; the relative phase-differences and amplitudes of the various waves change from instant to instant, so that if, at a given instant, they neutralise each other at a particular point, this neutralisation is only temporary, and is quickly succeeded by enhanced vibration due to the reinforcement of the waves. If it is remembered that many billions of light waves originate in the course of a second, it is easily seen why a white surface illuminated by a flame appears uniformly bright; the fluctuations of intensity follow each other so quickly, and vary over such short distances on the screen, that they cannot be perceived by the eye, which gains an impression due to the *average* condition of the screen. (See article *Wave Theory*, by Lord Rayleigh, Encyclopædia Britannica.)

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PIANO.—The annexed diagram is of the iron frame of a pianoforte. There is a stress of 20 tons tending to bring the two centre lines (AA and BB) together. The load is evenly distributed, and is taken by the four columns shown. The two outside columns may be made any size, but the two inside columns, at the places marked X, must not be over $\frac{3}{4}$" in width. How deep must they be made in order to carry the load with safety?

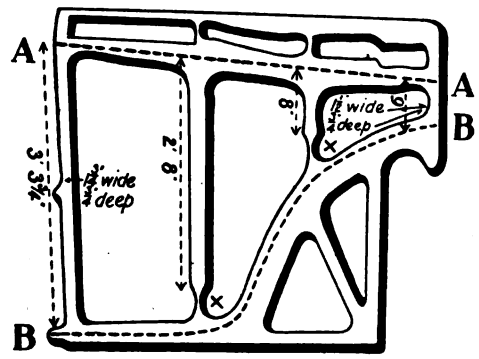

FIG. 1.—(PIANO.)

Assuming that the load is uniformly distributed, the load across each bay or panel $= \frac{20}{3} = 6\frac{2}{3}$ tons. The load on the two intermediate columns $= 6\frac{2}{3}$ tons each, and the load on each of the end columns $= 3\frac{1}{3}$ tons. It is, of course, no more than an approximate assumption that the load is uniformly distributed, because, for one reason, all instruments are not tri-chord throughout the seven octaves.

Let L = load at X = say 7 tons.

t = thickness of metal = $\frac{3}{4}$".

w = width of metal in inches.

s = safe working compressive stress of cast iron; say 6 tons per square inch.

Then $$L = t.w.s$$

and $$w = \frac{L}{ts},$$

i.e., $$w = \frac{7}{\frac{3}{4} \times 6} = \frac{28}{18} = 1{\cdot}55".$$

The section at x should therefore be at least $\frac{3}{4}" \times 1\frac{5}{8}"$, and might conveniently be made $\frac{3}{4}" \times 1\frac{3}{4}"$, or even 2".

It will be necessary to have the strings of the instrument coincident with the longitudinal centre-line of the columns when seen in end elevation, otherwise the tension of the strings will tend to produce bending in the columns. For this purpose it is desirable to employ columns which will be T-shaped in section except at X. With regard to the general design of these castings, attention is specially directed to the article on Modern Methods of Casting, in the July issue, and to the remarks *re* calculations at the foot of page 41.

THERMODYNAMICS. — If $y = a\,b^{(x-250)}$, find the value of y, when

$$\log a = \bar{3}{\cdot}56792$$
$$\log b = 1{\cdot}9965$$
$$x = 300.$$

$$\begin{aligned} \text{Log } y &= \log a + (x-250)\log b \\ &= \bar{3}{\cdot}56792 + 50\{0{\cdot}9965 - 1\} \\ &= \bar{3}{\cdot}56792 + 49{\cdot}8250 - 50 \\ &= \bar{3}{\cdot}56792 + \bar{1}{\cdot}8250 \\ &= \bar{3}{\cdot}39292 \\ \therefore\ y &= 0{\cdot}002471 \end{aligned}$$

BELT.—10 h.p. is transmitted to a pulley 12" diameter running at 1,500 revolutions per minute. Find the width of belt. The greatest tension is not to exceed 40 lbs. per inch of width. W = 0·43 lb. per foot length, square inch section: belt thickness $\frac{3}{16}$", $\mu = 0{\cdot}25$.

In the solution of this problem it is necessary to know what fraction of the circumference of the pulley is embraced by the belt. Assuming this fraction to be $\frac{1}{2}$, the angle of contact will be 180°. That part of the belt which is at any instant in contact with the pulley will be subjected to the action of centrifugal force, which will produce a tendency to urge the belt away from the pulley.

Hence a tension will be needed on the belt in order to counteract this tendency over and above the tension required to drive the pulley.

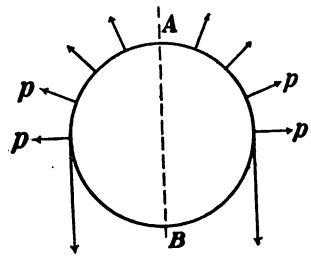

FIG. 1.—(BELT.)

Considering first the tension produced by centrifugal force, let the curved part of the belt be divided into an indefinitely large number of equal parts, and let p be the centrifugal force acting upon each of these parts. Let each of these small radial forces be resolved along and at right angles to the direction of the belt. Then if P is the tension on the belt required to balance the centrifugal force, the sum of the components along BA = 2P. It may be shown that for a semicircle, the ratio of the sum of all the radial forces to the sum of their components along the direction of the belt, is $\frac{\pi}{2}$. Since every particle of the curved part of the belt is subjected to a radial acceleration $= \frac{v^2}{gr}$, the sum of the radial forces must be $\frac{mv^2}{gr}$, if m is the weight of the curved part of the belt.

Hence $$\frac{\frac{mv^2}{gr}}{2P} = \frac{\pi}{2},$$

and therefore $$P = \frac{mv^2}{\pi gr} \quad \ldots\ldots\ldots \quad (a)$$

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If we divide P by the area of the belt section, we shall obtain the stress on the belt, *i.e.*, the force per unit of sectional area.

Let A = Area of belt section (square inches).
δ = Density of belt material (lbs. per 12 cubic inches).
L = πr = Length of curved part of belt (feet).

Then $m = \delta AL = \delta A \pi r$,

hence it is convenient to express r in feet and the belt section in square inches; it follows that the unit volume must be equal to that of a square prism 1 foot long by 1 inch square (that is, 12 cubic inches), for the volume is represented by $A\pi r$.

Substituting for m in (a) we obtain

$$P = \frac{\delta A v^2}{g},$$

and the stress produced

$$= \frac{P}{A} = \frac{\delta v^2}{g} \quad . \quad . \quad . \quad . \quad (b)$$

From the data supplied, $\delta = 0{\cdot}43$, and

$$v \text{ (ft. per sec.)} = \frac{2\pi r N}{60} = 78{\cdot}5,$$

N being revolutions per minute.

Substituting these values in (b), we find that the stress is 80 lbs. (say) per square inch.

As the belt is stated to be $\frac{3}{16}$" thick, the tension per inch of width is $\frac{3}{16} \times 80 = 15$ lbs. Subtracting this from the maximum tension allowed (*viz.*, 40 lbs.), we have 25 lbs. per inch of width for the tension needed to drive the pulley.

Excluding the tension due to centrifugal force, let T = tension on the tight side of the belt, and S = " " slack " "

Then h.p. transmitted

$$= \frac{(T - S)2\pi r N}{33{,}000},$$

and hence the effective tension

$$T - S = \frac{33{,}000 \text{ h.p.}}{2\pi r N}$$

(r being, as before, expressed in feet).

Substituting the given values, we obtain

$$T - S = 70 \text{ lbs.} \quad . \quad . \quad . \quad (c)$$

The least values that T and S may possess, in order that the belt may not slip, are such that

$$\frac{T}{S} = \epsilon^{\mu\theta},$$

when ϵ is the base of the hyperbolic system of logarithms,
θ is the angle of contact (radians),
μ is coefficient of friction between the belt and the pulley.

Taking logs of both sides of the equation,

$$\log T - \log S = \mu\theta \log \epsilon.$$

Substituting values on the right-hand side of the equation,

$$\log T - \log S = 0{\cdot}25 \times \pi \times 0{\cdot}4343 = 0{\cdot}341.$$

Hence the anti-log of $0{\cdot}341$ *i.e.*, $2{\cdot}193$ or (say) $2{\cdot}2$, is the value of $\frac{T}{S}$.

From this, $T = 2{\cdot}2\,S \quad . \quad . \quad . \quad . \quad (d)$

and from (c), $70 = T - S \quad . \quad . \quad . \quad . \quad (e)$

From (d) and (e) we obtain

$$S = 58{\cdot}3 \text{ lbs.},$$

and

$$T = (T - S) + S = 70 + 58{\cdot}3 = 128{\cdot}3 \text{ lbs.}$$

Since, after deducting the allowance for centrifugal tension, the greatest allowable tension is 25 lbs., it is evident that the width required will be $\frac{128{\cdot}3}{25} = 5{\cdot}125"$.

If we assume a belt to be stretched over two pulleys, then the sum of all the tensions on the two sides must be constant so long as the belt remains in contact with the pulley. If we assume a belt made of a material which has an indefinitely small density, then the relation between h.p. transmitted and the speed of the belt is shown by the curve A, Fig. 2, which is a straight line. If the density of the belt has a finite value, then as the speed increases from 0 the pull due to centrifugal force increases as v^2, as shown in the second curve B (Fig. 3), which is a parabola. If C is a curve of total belt tensions, and the ordinates of B represent the values of 2P, the vertical intercept at any point between B and C will represent the value of T + S when T is the driving tension and S the tension required to ensure the grip of the belt on the pulley.

Since the ratio $\frac{T}{S}$ is not affected by the speed, then $\frac{T - S}{T + S}$ is also a constant ratio, or

$$T - S = k(T + S).$$

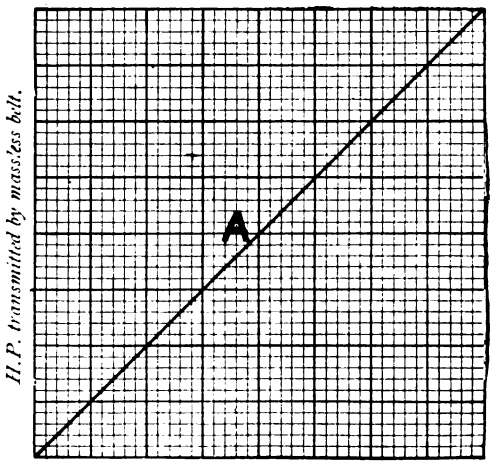

FIG. 2.—(BELT.)

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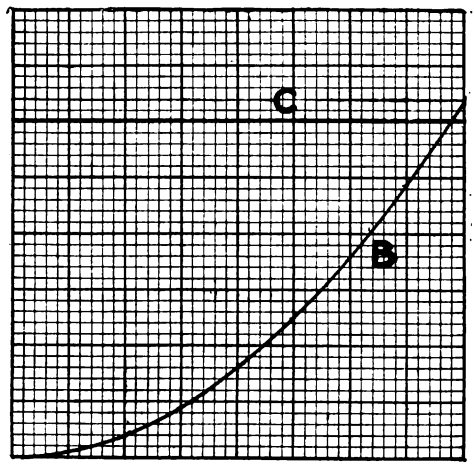

FIG. 3.—(BELT).

Hence the intercepts between C and B give a curve of the values of T − S with respect to the same speed base as before. But h.p. transmitted ∝ (T − S) v, and hence we may obtain a third curve D (Fig. 4), which shows the relationship between h.p. transmitted and the velocity of the belt. The speed at the point E is that at which the maximum h.p. is transmitted, and the speed at F is that at which the centrifugal tension just balances the initial stretch of the belt. Evidently at this point no power is transmitted, and any further increase of speed would cause the belt to leave the surface of the pulley.

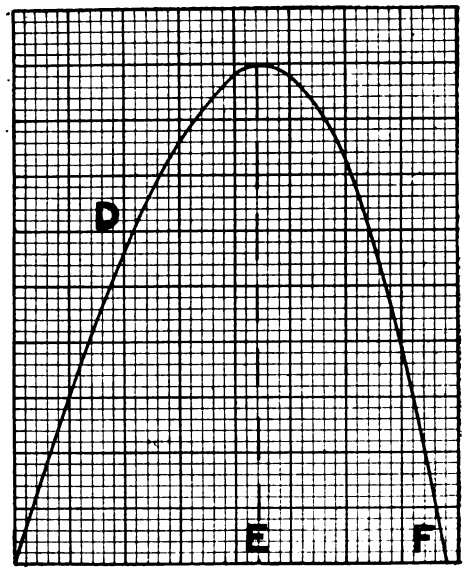

FIG. 4.—(BELT).

TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

DEAR SIR,—Some of your contemporaries in reviewing the article on Esparto which appeared in the May number of TECHNICS have made the mistake of confusing the work of Professor Trabut with that of Mr. John Christie. I should be glad if you would afford me space to give an explanation as to how the work was conducted for the illustration of these articles, as the original article on Esparto was not sufficiently explicit.

Your contemporary *The Papermaker* considers that the photograph of Esparto (Fig. 2.) is better than that shown in "Chambers's Encyclopædia." As far as my judgment goes, this is quite correct, and I think thanks are due to Professor Trabut for the pains that he has taken, and for the assistance that he has rendered for the illustration of the above article; but more than one of your contemporaries have made a mistake in supposing that Professor Trabut was responsible for the photo-micrographs also. I am indebted to Mr. John Christie for these, and I venture to think that without his co-operation my humble efforts in the production of this and subsequent articles would have failed to interest your readers. I take this opportunity of thanking Mr. Christie for the services that he has rendered and is rendering in the production of the above mentioned article and those that are to follow. Perhaps a few words of explanation from me might be of some interest to your readers. Fig. 1 in illustration of the fibrous constituents of Paper, No. 1, was supplied to me by Monsieur Trabut, Professeur à l'Ecole de Médecine, of Algiers. This is produced from a photograph, and is the first illustration, as far as my knowledge goes, showing the growth of Esparto in its wild state in the rocky land of the Hauts Plateaux of Algeria. Fig. 3, illustrating the pulling of the Esparto grass by the aid of the batonnet, is the reduced fac-simile of Plate xx. appearing in Professor Trabut's monograph on *l'Etude sur l'Halfa*, published in 1889, for which

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the author was awarded the first prize *au Concours ouvert par le Gouvernement Général de l'Algérie*, 1888.

Fig. 7 is a reproduction of a portion of Plate xii. in the same work; and Fig. 9 a portion of Plate xi., both somewhat reduced.

I am very much indebted to Professor Trabut for permitting me to reproduce these plates in illustration of my article. This was done in consequence of my having received a letter from the author, in which he said, "I authorize you to reproduce, either whole or in part, my work on Esparto." I hope in due course, with the co-operation of my friends, to avail myself of this kind permission.

I should like to call the attention of your readers to Figs. 4, 5, 6, 8, 10, 11, and 12. These are the work of my friend Mr. Christie, whose skill with the microscope and photo-micrographs are well known to the paper trade. I am unable to find any reproductions of photo-micrographs in any other works on the subject. The excellent Plates at the end of Cross & Bevan's book on Cellulose, published by Longmans in 1895, are drawn from photo-micrographs, and not process reproductions. The two devoted to Esparto are Plates vii. and viii. Professor Trabut in his work gives a drawing of a section of Esparto leaf in Plate ix. Unfortunately he does not show the rows of lignified fibres immediately under the epidermis, and those radiating from the epidermis to the fibro-vascular bundles which can be made prominent by the aid of certain colour reagents; nor does he show the wavy edge of the epidermis corresponding with the positions of the above mentioned lignified bundles of fibres.

I regret very much that at the time of writing the article I was not acquainted with Monsieur Marcel Rostaing's work on "Fabrication de la Pâte d'Alfa." Monsieur Rostaing, on reading my article in TECHNICS, was good enough to forward me a copy of his work. As your readers may know, Monsieur Rostaing is a member of the noted firm of Carson and Montgolfier, of Annonay. He has made a special study of Esparto, and the above-mentioned paper was contributed to the *Société d'Encouragement pour l'Industrie Nationale*, under the advice of M. Georges Lemoine, member of the Institute of France. For this work he was awarded a silver medal by the above-mentioned society. Had I been acquainted with his publication I should have made reference to it in my article. Monsieur Rostaing has also been good enough to forward me an author's copy of "*Précis Historique, Descriptif, Analytique, et Photo-micrographique des Végétaux propres à la Fabrication de la Cellulose et du Papier.*"

The first proof capable of any numerical expression of the "direction" of the fibres in a machine-made or hand-made paper was given when Mr. John Christie succeeded in splitting sections parallel with the surface, sufficiently thin to admit of photo-micrographs being taken, showing the actual direction of each individual fibre, as shown for the first time in Fig. 11 of the May number of TECHNICS. By the aid of this I was able to determine the direction of each fibre, and it is easy enough for anyone to see from these measurements why it is that a machine-made paper is so much stronger when pulled in the machine direction than in the cross direction. I learn from Mr. Christie that the mode of splitting into laminæ which he adopted was suggested to him by Mr. Roland Green, and that by following out his suggestions he was able to get a satisfactory result. In the July number of TECHNICS reproductions of photo-micrographs have appeared of sections of writing-paper cut at right angles to the surface, both in the machine and cross directions. These sections are the property of my friend Mr. R. W. Sindall, and prepared at his suggestion to demonstrate the reduction of space and improvement of surface due to glazing. We had an idea that such sections would enable us to determine the percentages of different fibres, but in this we were disappointed. M. Rostaing is working in the same direction, and has forwarded some of his photo-micrographs, which will be used in due course for the illustration of TECHNICS articles. Your contemporary, the *Paper Trade Review*, in commenting on the article on Esparto, has referred to the articles on "Esparto and its History" which were published by them in 1895. I was acquainted with these articles, and had them by me at the time. I made no reference to them, as I made no attempt to go into the history of the introduction of Esparto into this country beyond attempting to establish the date of its first use by the paper trade in general, and showing that a certain issue of the Society of Arts journal, reputed to have been printed on Esparto paper (see "Chambers's Encyclopædia"), was in reality a rag paper.

Yours faithfully,

CLAYTON BEADLE.

15, Boro', London Bridge.

To the Editor of TECHNICS.

DEAR SIR,—With reference to your correspondent's enquiry for a formula for the calculation of π, answered in the June number of TECHNICS, he probably, like myself and thousands of others, has tried to obtain a more simple method, and, of course, has failed.

You state, in reply to his question, that Archimedes was the first to set about this question in a methodical manner. I admit he was the first of whom we have any record, but must deny him the honour of being the first to discover that it is approximately equal to $3\frac{1}{7}$.

The Great Pyramid shows clearly that its designer knew very accurately the value of π, and you will admit that the Pyramid was built a couple of thousand years before Archimedes lived. Seeing, therefore, the value of π was known at this early period, it is difficult to imagine the knowledge confined to one man, and that it was lost on his death; be this,

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however, as it may, the fact remains that no record of the method of calculation has survived.

Now, although the method of calculating π was lost, I think it safe to assume that succeeding generations would be acquainted with the fact that its value is approximately $3\frac{1}{7}$; and as the Egyptians were a practical rather than a mathematical race, they would set about the question of re-discovering its value in a practical manner.

Before going into the calculation we must not forget that we have assumed that our ancient philosopher knew that π is approximately equal to $3\frac{1}{7}$; if therefore he could find a formula, empirical or otherwise, that would give this figure, he would be quite satisfied, and leave to his successors the task of refuting or confirming his result.

The following method with which I am crediting our ancient friend, but which, so far as I know, is quite original, was probably the way he tackled the question.

From practical experience he would know that the relative weights of cylinder, sphere and cone, whose heights and diameters are the same, were in the proportion of 3, 2 and 1; how easy for him to say: "Surely the enveloping cube has also a definite proportion to these solids," and proceed to work out the value of π on this assumption.

Now $2r$ = side of cube
= diameter and height of cylinder
= diameter of sphere
= diameter of base and height of cone.

The contents of these solids are respectively—

Cube.	Cylinder.	Sphere.	Cone.
$(2r)^3$	$2\pi r^3$	$\frac{4}{3}\pi r^3$	$\frac{2}{3}\pi r^3$

Eliminating fractions, by multiplying by 6, we obtain the relative values—

$$24r^3, \quad 6\pi r^3, \quad 4\pi r^3, \quad 2\pi r^3.$$

$$\text{Let } \pi x = 24; \quad \therefore x = \frac{24}{\pi}$$

The content of cube is therefore $= x\pi r^3$.

Substitute this value for the content of cube, and divide each expression by πr^3; the series then becomes—

$$x, \quad 6, \quad 4, \quad 2.$$

Next divide the sum of each successive pair by their difference—

$$\frac{x+6}{x-6}, \quad \frac{6+4}{6-4}, \quad \frac{4+2}{4-2}$$

$$= \frac{x+6}{x-6}, \quad 5, \quad 3$$

Now assume that 5 is a geometrical mean between $\frac{x+6}{x-6}$ and 3, and we arrive at this equation—

$$25 = \frac{3(x+6)}{(x-6)};$$

$$\text{or, } 25x - 150 = 3x + 18$$

$$22x = 168,$$

$$\text{but } x = \frac{24}{\pi};$$

$$\therefore \frac{22 \times 24}{\pi} = 168, \quad \therefore \pi = \frac{22 \times 24}{168}$$

$$= \frac{22}{7} = 3\frac{1}{7}.$$

This, of course, is not "Mathematics," but we must not forget that three to four thousand years ago was hardly a mathematical age. Mathematics was not taken up seriously as a general study until the time of Pythagoras, about B.C. 580. The great Pyramid of Cheops was built probably 1500 years before this, and yet the value of π is very clearly and accurately worked into its formation.

Yours faithfully,

F. BROWN, Capt. A.O.D. (Wh. Sc.)

Dover, July 1st, 1904.

[Captain Brown's method of obtaining an approximate value of π is of considerable interest; but it may be questioned whether this is a method likely to have been used at an early date. It is probable that the philosopher who first attacked the problem would no more have thought of an abstract investigation than he would of questioning the reality of the material universe. Is it not most probable that he measured the circumference by the aid of a strip of parchment, and then found its ratio to the measured diameter?—ED.]

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded to the "Technics" Prizeman.

£25 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 87 competitions have been given in the preceding eight numbers of TECHNICS.

The present number contains particulars of 7 competitions, for which money prizes amounting, in the aggregate, to £25 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£25 IN PRIZES.

General Rules.

Competitors are requested to note the following rules :—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, TECHNICS, 12, Burleigh Street, Strand, W.C., and must reach these offices not later than October 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

PHYSICS.

£3 for the best answer.

Describe and criticise in detail the Electron Theory of Matter.

ELECTRICAL ENGINEERING.

£3 for the best answer.

Describe and criticise the best types of commercial ammeters and voltmeters, for direct and for alternating currents, with which you are acquainted ; give diagrams.

MECHANICAL ENGINEERING.

£3 for the best answer.

Investigate the properties of an epicyclic train, and describe the most important uses of epicyclic trains in modern machinery.

CHEMISTRY.

£3 for the best answer.

Write an essay on mass action and the phase rule.

INSTRUMENT DESIGN.

£3 for the best answer.

Design a constant pressure air thermometer for quantitative use by students, paying attention to the theoretical requirements of the instrument, the time required for a complete experiment (not to exceed an hour and a half), and cheapness of construction.

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THEORY OF STRUCTURAL DESIGN.

£5 for the best set of answers.

1. Cast iron has greater compressive strength than mild steel: why is it not used more frequently for pillars, etc.?

2. What pillar formula do you usually employ for built-up mild steel pillars with flat ends, to carry a dead load. The numerical value of the constants should be given. Tabulate the safe load in tons per square inch for the following values of *length ÷ least radius of equivalence* :—

0, 10, 20, 40, 60, 80, 100, 120, 140.

The factor of safety in each case is to be taken as

$$4 + \frac{k}{100}$$

where k = length ÷ least radius of equivalence. Perform a similar set of operations, using the pillar formula given in this issue. If the radius of equivalence (or gyration) is not involved in your favourite formula, assume, for purposes of comparison, that radius of equivalence = $\frac{1}{4}$ × least diameter. Re-read August issue for terms, etc.

3. Illustrate, by sectional plans, several methods of protecting built-up mild steel pillars from injury by fire.

4. Describe in detail, with sketches, the method of preparing and fixing bases and caps suitable for solid cylindrical rolled steel pillars up to six inches diameter.

COTTON SPINNING.

£5 for the best set of answers.

1. State the spaces which should be left clear between different machines in a cotton mill, and explain why the spaces you give are necessary.

2. Give a brief description of the uses of each machine represented in Fig. 2, p. 288.

3. Explain the table given on p. 289.

4. Give a brief description of the system of power distribution which you consider to be most suitable for a cotton mill.

RESULTS OF JUNE COMPETITIONS.

THEORY OF CAPILLARITY.

PRIZE, £3.—A. Ghee, Fairfield, Eaton Park Road, Winchmore Hill, N.

SPECIAL HONOURABLE MENTION :—S. Irwin Crookes; Edgar P. Hedley; J. F. Briggs.

HONOURABLE MENTION :—W. G. Poupard; J. E. Tytler; William J Williams.

DYNAMICS.

PRIZE, £3.—Ernest W. Sanders, 34, Cambridge Street, Pimlico, S.W.

SPECIAL HONOURABLE MENTION :—James A. Cole; John F. Tunch; A. Macdiarmid; H. H. Francis Hyndman; W. Cassels Brown; W. Winkworth.

HONOURABLE MENTION :—S. Irwin Crookes; Percival Charles Franklin; Harold Slicer.

CONSERVATION OF ENERGY.

PRIZE, £3.—Frank S. Easton, 1, Knowe Terrace, Pollokshields, Glasgow.

SPECIAL HONOURABLE MENTION :—Ernest W. Sanders; Hugh J. Williams; David Fulton; J. M. Young; A. E. Linnell; Robert H. Buckie; John Roberts, jun.

HONOURABLE MENTION :—Joseph Leaper; J. T. Spittle; S. Irwin Crookes; A. Richards; G. Royds; Harold Slicer; Wm. H. Hollinrake; W. Cassels Brown; John Thomson; James A. Cole; T. Howard Harris.

ELECTRO-CHEMISTRY.

PRIZE, £3.—Albert E. Marshall, Granville House, Thornton, Preston, Lancs.

ELECTRICITY.

PRIZE, £3 (divided equally between two competitors).—F. A. Haigh, Briargate, Warwick Drive, Hale, Altrincham; D. H. Bishop, 5, Doveridge Place, Walsall.

SPECIAL HONOURABLE MENTION :—A. Ghee; H. W. Kefford; H. H. Francis Hyndman; H. A. Stewart; John Roberts, jun.; H. J. Trust.

HONOURABLE MENTION :—F. Shaw.

THEORY OF STRUCTURAL DESIGN.

PRIZE, £5.—Percy J. Robinson, Engineer's Dept., District Office, Hamilton, N.B.

SPECIAL HONOURABLE MENTION :—K. Bonallo; Frank S. Easton; J. M. Young.

HONOURABLE MENTION :—Henry James Jones; J. M. Chippendale; A. G. Lee; W. J. Richards.

DYNAMOS AND MOTORS.

PRIZE, £5.—P. E. Banting, Mona House, Manor Road, Rugby.

SPECIAL HONOURABLE MENTION :—Claude Youatt; A. Ghee; N. Thirlby; D. H. Bishop; W. Gillespie.

HONOURABLE MENTION :—L. J. Lepine; Frederick B. Magee; S. E. Allen; Jos. W. Beswick; W. Cassels Brown.

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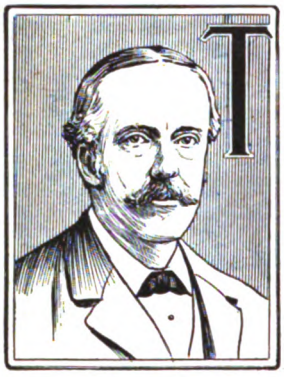
EDITORIAL.

The Electron Theory of Matter.



THE address delivered at Cambridge by Mr. A. J. Balfour, as President of the British Association, has forcibly called the attention of the public to a theory of the constitution of matter recently proposed by Professor J. J. Thomson. From the earliest times physicists have striven to construct a mechanical theory of the universe in terms of matter and motion; in this connection, "matter" must be understood to mean, not any particular chemical element, but some primordial substance which acquires energy when set in motion. Such a theory, it need hardly be remarked, still falls short of completely explaining the universe, since our pleasures and pains, and indeed all our sensations, lie outside its scope; the pain of an attack of toothache, for instance, is not, to the sufferer, a phenomenon explicable as a manifestation of energy. Nevertheless, a theory which can link together all physical phenomena of the universe is sufficiently wide to evoke our keenest admiration.

The two fundamental properties of matter which must be explained by a theory such as we are discussing, are (1) the Newtonian attraction of two small portions of matter, with a force varying directly as the product of their masses, and inversely as the square of the distance separating them; and (2) the inertia of matter, or that property which entails the expenditure of work in setting matter in motion. To what extent can these properties be explained in terms of the electron theory? Before answering this question, it may be best to give a brief outline of the electron theory itself.

The electro-magnetic theory, as left by Maxwell, may be said to have consisted of two sets of differential equations and their solution; each set being merely the mathematical expression of an empirical law. For many years this theory attracted little attention, probably owing to its abstruse character; but Professor J. J. Thomson succeeded in translating it into a form which could be readily visualised, with the result that many phenomena, far too complex to be investigated mathematically, can be qualitatively explained by its aid. Faraday conceived the existence of tubes of force joining opposite electrical charges, and deduced the property that these tubes tend to contract longitudinally, and to expand laterally. Professor J. J. Thomson showed that these tubes, when set in motion at right angles to their lengths, produce a magnetic field perpendicular to the length of the tube and the direction of motion. Since a magnetic field is known to contain a store of energy, it follows that a moving Faraday tube possesses energy: in other words, a Faraday tube possesses inertia, requiring work to be expended in order to set it in motion, and when in motion, being capable of performing work on any body which stops it.

Experiments have shown that minute negatively charged particles, possessing about a one-thousandth part of the inertia of an hydrogen atom, are projected from the cathode of a vacuum tube; and Professor J. J. Thomson has proved, in analysing a remarkable series of experiments due to Kaufmann, that the actual inertia of each of these particles is quantitatively equal to that due to the Faraday tubes ending on the particle. As a secondary consequence, it was found that the linear dimensions of each particle (or electron) are of the order of magnitude of 5×10^{-14} cm., a length very small in comparison with the estimated linear dimensions of an atom (*i.e.*, about 10^{-8} cm.).

The next step taken by Professor J. J. Thomson was to assume that the inertia of an atom is really due to a number of negative electrons comprised in it; more strictly speaking, we should say that the inertia is due to the Faraday tubes ending on the negative electrons. The positively charged part of an atom appears to be of atomic dimensions; and if this is so, it follows that the positive charge (or rather the Faraday tubes ending on it) will possess little inertia. The reason of this can be easily explained. The inertia per unit length of a Faraday tube varies inversely as the sectional area of the tube; if we imagine a given number of tubes

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to issue normally from the surface of a sphere, the combined sectional areas of all the tubes when they leave the sphere being just equal to the area of the latter, then it is clear that the smaller the sphere is, the smaller will be the sectional area of each tube when it leaves the sphere. A Faraday tube of large sectional area will possess little inertia; it is, therefore, practically only that part of a tube which lies near the surface of the electron from which it issues, that will possess appreciable inertia, and the negative electron being much smaller than the positive electron, the former will possess the greater inertia. This meets an objection that would otherwise arise, in so far as the distribution of the tubes of force joining one atom to another would be altered by any form of chemical change, and experiments have shown that the inertia of matter is not appreciably altered by chemical change. The above reasoning shows that it is only the wider parts of the Faraday tubes, at a relatively great distance from the negative electron, that would be modified during a chemical reaction; and consequently the inertia of an atom is sensibly constant.

Without going further into details, it appears that the electron theory is capable of furnishing an intelligible explanation of the inertia of matter. It also explains, in a general manner, the differences in the chemical properties of the elements, and from it we might anticipate that these should be periodic functions of the atomic weights of the elements —a result originally deduced empirically by Mendeléeff and Newlands. Some light is also thrown on the peculiarities of the line spectra of the elements: in passing, it may be remarked that the study of spectroscopy will probably, in the end, lead to a detailed knowledge of atomic structure, since, if we know the various ways in which a mechanical system is capable of vibrating, we have a most valuable clue to the structure of the system. So far, then, the electron theory may be considered to be satisfactory, and for the moment we feel inclined to agree with Mr. Balfour when he says, "All will, I think, admit that so bold an attempt to unify physical nature excites feelings of the most acute intellectual gratification. The satisfaction it gives is almost æsthetic in its intensity and quality. We feel the same sort of pleasurable shock as when, from the crest of some melancholy pass, we first see far below us the sudden glories of plain, river, and mountain."

But there is another side to the question, which must not be overlooked. We have found an explanation of the inertia of matter, or rather, we have assumed that inertia is really a property of the ether contained within the Faraday tubes ending on negative electrons; but how about the Newtonian attraction of matter for matter? No explanation of this fundamental property of matter appears to be forthcoming, and it is difficult to imagine any extension of the electron theory which will help us in this connection. We therefore feel forced to enquire, Can a theory which gives no explanation of one of the fundamental properties of matter, be justly entitled "a theory of the constitution of matter"? Of late years many of our most eminent scientists have been engaged in the investigation of the electrical properties of matter; and no one who considers the important discoveries made as a consequence of this line of study, can for a moment doubt that the labour spent has been amply rewarded. But the phenomena which have been brought within a measurable distance of explanation are, so to speak, of secondary importance; many of these phenomena had not even been observed till quite recent times. The phenomena of gravitation, which must have been amongst the earliest observed by man, are the most difficult to account for on any theory of the constitution of matter; nevertheless, a theory which gives, and pretends to give, no explanation of these phenomena, can hardly be said to unify our knowledge of the universe, and cannot be accepted as anything but a temporary substitute for the complete theory which we hope will be evolved in the future.

When the above considerations are taken into account, the following passage from Mr. Balfour's address cannot fail to strike us as embodying a rather premature disparagement of the beliefs held by scientific men up to recent times:—

"It may seem singular that down to, say, five years ago, our race has, without exception, lived and died in a world of illusions; and that its illusions, or those with which we are here alone concerned, have not been about things remote or abstract, things transcendental or divine, but about what men see and handle, about those "plain matters of fact," among which common sense daily moves with its most confident step and most self-satisfied smile."

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PERSONAL ITEMS.

ABOUT a year ago, the rejection of a large percentage of candidates for military service, for physical defects, led to the appointment of a committee to enquire whether or no the English race is deteriorating. It is satisfactory to learn from the report of this committee that, though much can and should be done to improve the physical well-being of the nation, yet there is no marked sign of deterioration discernible.

A STANDING committee on machinery designs has been appointed by the Admiralty. Prof. A. B. W. Kennedy is to act as President, the other members of the committee being Engineer Rear-Admiral J. A. Smith, and Mr. J. T. Milton, chief engineer-surveyor to Lloyd's Register.

THE annual meeting of the Society of Chemical Industry will take place in New York from September 7th to 12th. The President, Sir William Ramsay, will deliver an address, and interesting tours have been arranged. Particulars can be obtained from the secretary of the Society, at Palace Chambers, 9, Bridge Street, Westminster.

DR. FRANCIS GALTON has just concluded an investigation into the distribution of success and of natural ability among the kinsfolk of Fellows of the Royal Society. The result of the enquiry proves the existence of a small number of more or less isolated hereditary centres, round which a large part of the total scientific ability of the nation is clustered, with a closeness that rapidly diminishes as the remoteness of kinship from its centre increases.

THE first annual convention of the British Foundrymen's Association was begun on August 2nd, at Manchester. The inaugural address was delivered by Mr. Buchanan. Mr. Percy Longmuir read a paper on the microstructure of metals, illustrated by photo-micrographs of types of cast iron, steel, brass, and bronze; and Mr. W. T. MacCall read a paper on strength tests of cast metals.

THE war appears in no way to affect the steady pursuit of science in Japan. The Journal of the College of Science of Tokyo is issued as usual, and shows how keen Japanese students are in the investigation of natural phenomena.

PROF. W. E. DALBY has been appointed Professor of Civil and Mechanical Engineering at the Central Technical College, South Kensington, in place of Prof. W. C. Unwin, who has resigned.

THE Senate of the University of London has accepted the offer of £5,000 from the Goldsmiths' Company, to enable the classes of a polytechnic character to be carried on during the session 1904–5, at the Goldsmiths' Institute, New Cross. The classes to be carried on during the session will be arranged by the Senate of the University in consultation with the London County Council.

THE *Fortnightly Review* for August contains an interesting article by Mr. W. B. Woodgate, advocating a barrage scheme for the Thames. He recommends the construction of a dam of masonry across the river at Gravesend, provided with a public highway above and a railway tunnel through its foundations. Four locks would serve to pass shipping from the estuary to the upper water. The effect of the dam would be to stop tidal action above Gravesend, the river above the dam being converted into a diluvial lake extending as far as Richmond. The estimated cost is £3,700,000.

THE "reliability" trials of motor-boats, which were made in Southampton Water, have now been completed. The only boat to obtain full marks was the little vessel, 18 ft. long by 5 ft. 6 in. wide, entered by the Seal Motor Co., and built by Maynard, of Chiswick.

THE standard voltages recommended by the Engineering Standards Committee are as follows:—

Alternating or direct current, at the consumer's terminals	110, 220, 440, and 500 volts.
Alternating current at generator terminals .	2,200, 3,300, 6,600, and 11,000 volts.
Standard pressure at secondary terminals of alternating transformers	115, 230, 460 and 525 volts at no load.
Standard pressure at terminals of direct current traction motors. . .	500 volts.

A variation of 10 per cent. either way is permitted in the above figures.

THE bad state of the cotton industry is much to be regretted; in Lancashire it is proposed to reduce the working hours of the mills from 47½ to 40 hours per week. In the United States things are even worse, for, in addition to shortening the working hours, it is proposed to reduce wages by 12½ per cent.

AN American court has just decided that an agreement to employ none but trade union labour is unenforceable as law, as it constitutes a contract in restraint of trade and of the liberty of the subject, and creates a monopoly in favour of trade unionists to the exclusion of other workers.

THE coal mined in Japan amounted to 3,100,000 tons in 1892, and to 8,945,939 tons in 1901. In 1892, the consumption of coal amounted to 1,700,000 tons, and in 1901 to 6,600,000 tons. If, as Prof. Perry contends, advance in civilisation goes hand-in-hand with utilisation of power, and the general supply of power on a large scale is dependent on coal, the above figures indicate the progress made by Japan in nine years.

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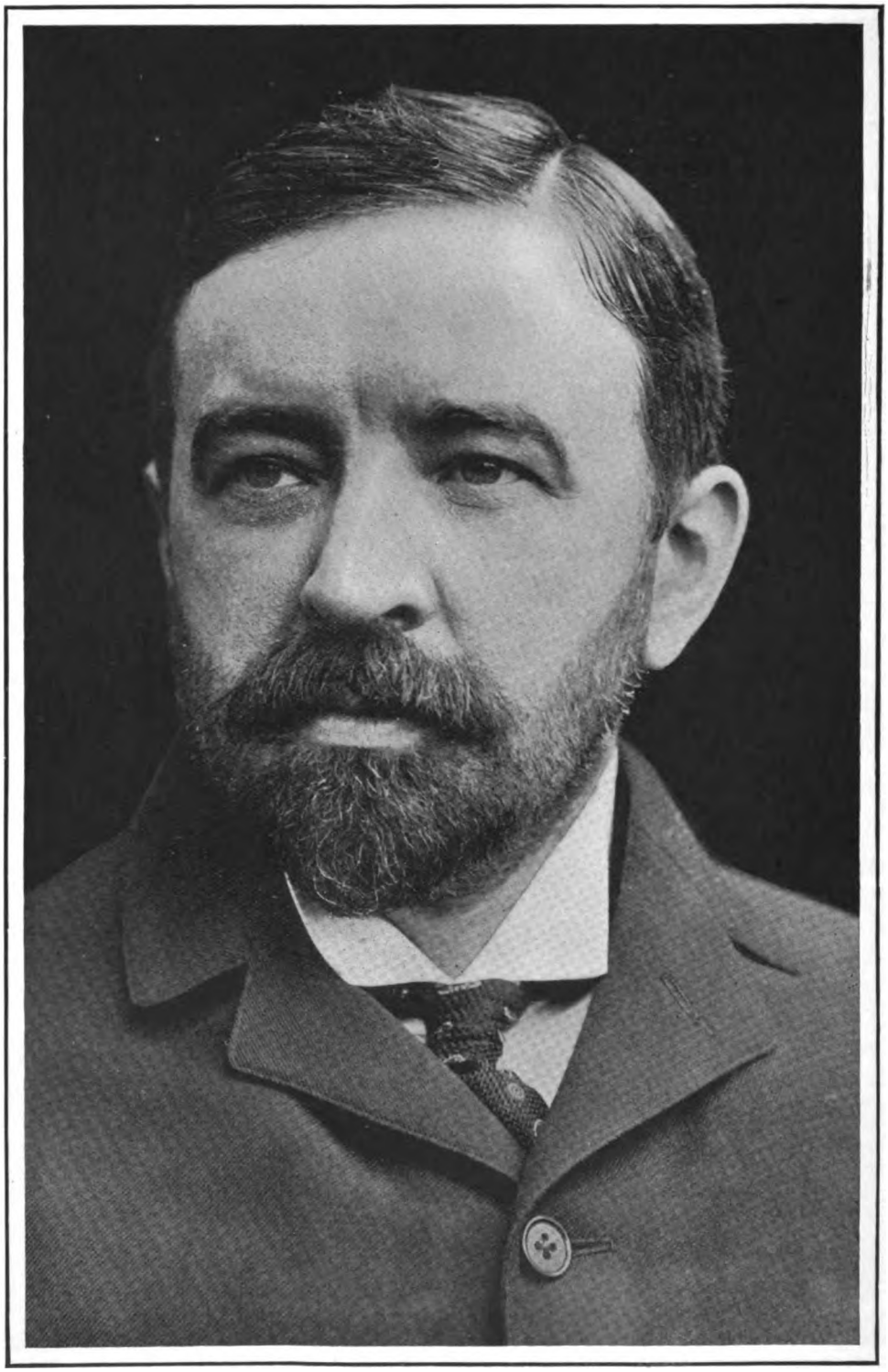

HORACE FIELD PARSHALL, M.I.C.E., M.I.E.E.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. II. OCTOBER, 1904. No. 10.

PROGRESS OF SCIENCE AND TECHNOLOGY.

A NUMBER of interesting communications relating to radio-activity were made at the Cambridge meeting of the British Association in August last. Lord Kelvin stated that the earlier opinions regarding radium, to the effect that its emission of energy goes on for ever, had so alarmed him that he felt obliged to maintain that energy is derived from some external radiations absorbed by the radium. It has since been made plain that the radium atom has a life of limited duration (about 30,000 years) so that the above difficulty no longer exists, and therefore Lord Kelvin withdrew his opposition to the disintegration theory. Further, Lord Kelvin exhibited models illustrating the behaviour of the radium atom. One of these consisted of two positively charged spheres (representing positively charged atoms) with a small negatively charged sphere (representing a negative electron) between them. The large spheres are held together by the interposed negative charge, but the state of equilibrium is unstable; a disturbance would cause one of the positively charged spheres to be projected away with considerable velocity. Lord Kelvin pointed out that if the structure of the radium atom were really like that represented by his model, the rate of disintegration would be greater at high than at low temperatures, which has been proved experimentally not to be the case; thus the models exhibited can only be considered to offer a partial and tentative explanation of the structure of radio-active atoms.

Latest Opinions on Radio-Activity

Professor J. J. Thomson made some interesting observations on radio-activity. He pointed out that McClellan and Strutt had simultaneously shown that the air contained by closed metal vessels has the capacity of discharging an electroscope; this is not a property merely of the air, since it depends on the metal composing the enclosing vessel, as well as on the volume of the vessel. With vessels of a litre volume the leak with lead is twice that with zinc. Further, if the vessel is placed within a lead cistern the ionisation is decreased. In fact, if a sheet of lead is held above the closed vessel, so as to shield it from the sky, the rate of ionisation is diminished; if the sheet of lead is held below the vessel, so as to shield it from the earth, the ionisation is also diminished. Mr. Cook, in Canada, surrounded his apparatus with a lead vessel weighing half a ton, and found that the decrease produced in the ionisation was no greater than with an enveloping lead vessel two inches in thickness. A student at the Cavendish laboratory has sunk apparatus, similar to that described above, to a depth of 60 ft. in a lake, and found that there is still a residual ionisation. As a final result, it appears that every metal is to a certain extent radio-active, and emits two kinds of radiations, one of which is very penetrating, while the other is absorbed with comparative ease. The easily absorbed radiations from carbon have been found to be more penetrating than those from lead. There remains the possibility that all space is traversed by exceedingly penetrating radiations, which, falling on metals, cause the emission of radiations.

PERHAPS one of the most remarkable communications to the British Association was that of Mr. R. A. Hadfield, who described Dr. Heusler's magnetic alloys made from non-magnetic materials. When copper is alloyed with manganese and

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aluminium a substance is obtained which possesses high permeability. For a given percentage of manganese, the best results are obtained when the percentage of aluminium is, roughly, half that of manganese; this corresponds to one atom of aluminium to one of manganese. An alloy containing 60 per cent. of copper, 26 per cent. of manganese, and 14 per cent. of aluminium is practically as magnetic as cast iron; unfortunately the alloy is very brittle, and cannot be drawn or forged. If iron is added to this alloy it becomes non-magnetic, so that we reach the conclusion that a magnetic substance can be made by combining substances which are themselves non-magnetic, and the addition of a magnetic substance renders the final product unmagnetic. It used to be thought that the magnetic properties of iron were due to some peculiarities of the iron atom, a conclusion to which it was hard to subscribe, owing to the circumstance that at high temperatures iron is non-magnetic. It now appears that the magnetic properties of a substance are due to some peculiarity in the grouping of the atoms within the molecule, or perhaps within the more complex aggregates in which atoms arrange themselves in solids.

Magnetic Alloy of Copper, Manganese, and Aluminium

Dr. Lummer, of Charlottenburg, opened an interesting discussion on N rays. He stated that, in his opinion, the only excuse for discussing the subject is that the French Academy nad recently awarded a prize to Blondlot for his work on N rays. Dr. Lummer expressed the opinion that the observations which have been described as proving the existence of N rays depend on physiological, and perhaps psychological, conditions of the observer. Finally, he asked those amongst his audience who had experimented on the subject to raise their hands; in response fifteen hands were raised. He next requested those amongst the fifteen observers who had obtained any evidence in support of N rays to raise their hands; only one hand was raised. Altogether the general feeling of the meeting was one of fairly marked scepticism.

N Rays

Professor Barrett and Mr. Hadfield have found that the thermal conductivities of manganese-iron, nickel-iron, and tungsten-iron alloys vary in a manner exactly parallel to the variation of the electrical conductivities; in other words, when an ailoy of iron and any one of the metals mentioned is found to possess a low electrical conductivity, it will also possess a low thermal conductivity.

Thermal Conductivity of Iron Alloys

All flame standards of light are known to vary with the barometric pressure and the humidity of the atmosphere; careful experiments have recently been carried out at the National Physical Laboratory, in order to determine the exact variation of the Harcourt 10 candle-power pentane standard, and the results were communicated to the British Association by Mr. Clifford C. Paterson. It has been found most convenient to express the effects of humidity in terms of litres of aqueous vapour per cubic meter of dry air, at the barometric pressure existing at the time of the experiment. Let b = barometer reading, in millimeters; e = pressure of aqueous vapour; e = pressure due to the carbon dioxide in the atmosphere; then ϵ, the number of litres of aqueous vapour per cubic meter of air, is given by the equation

Candle-power of the Harcourt Pentane Lamp

$$\epsilon = \frac{e}{b - e - e'} \times 1{,}000$$

It appears that the candle-power of the pentane standard lamp is diminished by about 0·7 per cent. for each litre of aqueous vapour per cubic meter of air. The exact formula for the candle-power of a nominally 10 candle-power pentane lamp is given by the equation—

$$\text{Candle-power} = 10 + 0{\cdot}066\,(10 - \epsilon) - 0{\cdot}008\,(760 - b).$$

Experiments carried out at the Reichsanstalt have shown that the Hefner-Alteneck standard lamp, in which amyl acetate is burnt by means of a wick, is also subject to variation due to changes of barometric pressure and humidity; it has been found that the candle-power is diminished by 0·5 per cent. for each cubic litre of aqueous vapour in the atmosphere.

In determining the candle-power of a gas-flame, by the aid of the Harcourt or the Hefner-Alteneck standard, no serious inaccuracy is incurred, since it is probable that both the flame to be tested and the standard vary in the same manner, owing to a change of barometric pressure or of humidity; it is possible, however, that the light from the incandescent gas mantle does not vary in the same manner. In testing electric lamps an error of 4 per cent. may be made if a flame

Photometric Standards

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standard lamp is used. Professor Fleming has therefore constructed an incandescent electric lamp to be used as a standard in photometric tests; in this case, since the incandescent filament is in no way affected by the atmosphere, the sources of error described above are eliminated. The principle underlying the construction of these lamps is thus described by Professor Fleming :—

Electric Glow Lamp Standard

It is well known that some types of carbon-filament glow lamp, when worked at constant voltage, slightly increase in candle-power for the first 50 hours or so of their life. After that time a stationary period is reached, and then a progressive drop in candle-power takes place. The initial rise in candle-power is due to a gradual consolidation in the filament with use, which reduces its resistance; and the subsequent decay in candle-power is chiefly due to the deposit of carbon upon the bulb. The surface of an ordinary 16 candle-power incandescent lamp is approximately equal to that of a sphere three centimeters in radius, and may be taken roughly as 120 square centimeters. Accordingly, an ordinary small-bulb incandescent lamp is not very suitable as a standard lamp. The writer found, however, that by enclosing the filament in a bulb of much greater diameter, say in a cylindrical bulb twelve centimeters in diameter and twenty centimeters in length, giving a total bulb surface of nearly 800 to 1,000 square centimeters, the deposit of carbon upon the bulb was greatly diminished: first, because the glass is further removed from the filament, and, therefore, the chances of a carbon molecule getting on to the glass are reduced; and, secondly, because the carbon that is deposited is spread over a much larger area of glass, so that its effect in interfering with the passage of light is greatly diminished. Again, it was found that by subjecting the carbon filament to a certain process of ageing in another bulb before transferring it to the large bulb, the rise in the resistance of the filament was, so to speak, anticipated. Accordingly, lamps were made to the following specification: Well-selected carbon filaments of the single-loop type of 10 candle-power or 16 candle-power were aged and adjusted to an efficiency of 3·5 watts a candle. These filaments were then transferred to large cylindrical bulbs of very clear glass and finished in the usual manner.

Such a large-bulb lamp may be called a photometric lamp. A mark is placed on the glass or on the collar of the lamp in such a position that when the lamp is mounted in the photometer with this mark facing the photometer disc, the axis of the lamp being vertical, the plane containing the horse-shoe filament is perpendicular to the line joining the lamp with the photometric disc. Each standard lamp is marked with the voltage at which it will give a certain candle-power in the above-mentioned direction and position. A lamp is then used as follows: Assuming it to be marked, say, 16 candle-power at 98 volts, the lamp is placed in the photometric gallery at a distance from the photometer disc of 4 ft.—*viz.*, the square root of 16—and by means of a potentiometer and variable resistance, the electric pressure on the terminals of the lamp is adjusted to be 98 volts. In these circumstances the illumination on the photometer disc is *one candle-foot*. This is balanced by placing on the other side of the photometer disc another incandescent lamp worked at about the same watts per candle, the distance of this last lamp (called the comparison lamp) being adjusted until a photometric balance is obtained. The standard lamp is then removed from the photometer, and its place is taken by any lamp the candle-power of which it is desired to ascertain at a certain voltage. The voltage having been adjusted, this last lamp is then moved to or from the photometer disc until it photometrically balances the comparison lamp. Let us imagine that it balances the comparison lamp at a distance of 50 in. The candle-power of this last lamp is then equal to 17·36 candles, being to the standard lamp in the ratio of the square of 50 to the square of 48. Such an operation has been called by the author a "photometric double weighing," because it resembles the process by which the exact weight of an object can be ascertained by means of good weights with an imperfect balance. By following the above method no want of symmetry in the photometer vitiates the process of measurement, neither are we concerned with the exact value of the comparison lamp so long as it remains constant during the experiment. All that we are concerned with is the exact value of the standard lamp used for setting the comparison lamp, and with the ratio of the distance of the standard lamp from the photometer disc to that of the measured lamp. Hence, if the distances are correctly measured, we have the exact ratio between the candle-power of the standard lamp and that of the lamp being measured.*

Professor Fleming has found that the candle-power of these lamps is not affected by the temperature of the atmosphere; they have been tested at the National Physical Laboratory at Bushy House, and also at the Reichsanstalt, Germany, and the discrepancy between the two tests does not exceed 1 part in 1,000.

Radio-activity and Matter

CLEMENS WINKLER has called attention, in an article which recently appeared in the *Chemical News*, to the danger that arises from attempting to deduce the existence of an element from physical properties alone. Thus he points out that in the early

* Paper read before the British Association at Cambridge.

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days of spectrum analysis, when the discovery of this new method of observation had produced a state of agitation similar to that now excited by the discovery of radio-activity, it was believed in all seriousness that calcium had been decomposed, because it had been found possible to cause the disappearance of the green line of its spectrum in one of the parts obtained by the fractional precipitation of a solution of calcium chloride. The question is raised as to whether, in the majority of cases, radio-activity is not a purely physical process, or a property which may be induced in matter without influencing its chemical composition, in much the same way that a piece of iron ore may become magnetised. In this connection it is noteworthy that radium is never found associated with the element barium in any of its common ores, but invariably with uranium, which was not only the first of the radio-active elements to be discovered, but is now regarded by many writers as the source of all radio-activity.

THE possible analogy between the structure of the atom, and the planetary system, as demonstrated more especially by its characteristic spectrum, has been repeatedly discussed. The disintegration theory of radio-activity accounts for the liberation of energy by radio-active bodies by assuming that after a certain average interval of time this sub-atomic system comes into an unstable configuration, and tumbles to pieces with great liberation of energy. In considering the large number of atoms contained even in a single milligram of salt, this liberation of energy would appear to be continuous. An alternative theory has been suggested by Mons. Filippoke, who has suggested that the energy of the radio-active elements is not due to the destruction of the atom, but rather represents a part of its heat of formation. The suggestion is made that whereas the smaller atoms, like the minor celestial systems, have reached a final condition, in which all available energy has been liberated, the larger atoms are still, for the most part, in a condition similar to that of the solar system, and will remain sources of energy until the whole of the supply represented by the "heat of formation" of the atom has been exhausted.

Heat of Formation of the Atom

THE petrol carburettor, and the requirements for its correct action under all the conditions met with in the running of the engine of a modern motor car are, as a rule, little understood.

Petrol Carburettors

The float feed spray carburettor, which was introduced by Herr Maybach, was used in its simple form almost exclusively until about two years ago.

This carburettor in its ordinary form is only suitable for an engine running under fairly uniform load at approximately constant speed, or at constant speed with a varying load when the engine is fitted with a "hit-and-miss" exhaust governor; but this form of governor is now practically extinct so far as motor cars are concerned. The object of the float and levers is to maintain the petrol at a constant level in the jet. The petrol in the float chamber lifts the float, which causes the levers to push down the needle valve and so cut off the supply, until such time as the level is again lowered by petrol being drawn out of the jet.

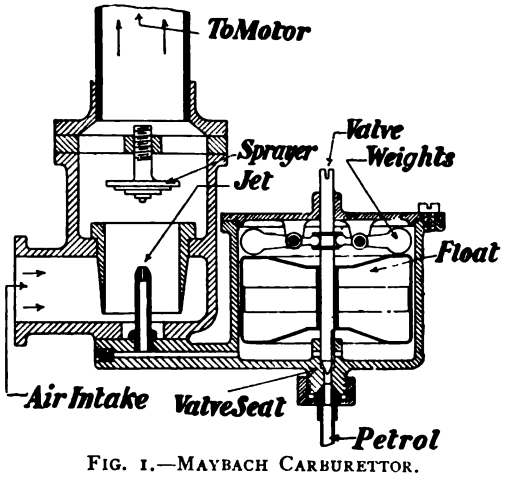

FIG. 1.—MAYBACH CARBURETTOR.

This arrangement of float feed is retained in most of the modern carburettors operated by the motor suction. The jet stands in the induction pipe of the engine, so that on the suction stroke the air passing it at a high velocity draws petrol out and mixes with it, the passages being so proportioned that a correct explosive mixture is formed, which passes to the cylinder. It is clear that if the horse-power per revolution is to remain constant the quantity of mixture used must vary directly as the speed of the engine; also, to give complete combustion and avoid waste, the proportions of petrol and air must remain the same.

As the air is drawn into the cylinder by

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the piston on its suction stroke, its velocity is due solely to difference of pressure; and to get more air through the same ports when the engine runs faster, a greater difference of pressure is required. As the atmospheric pressure remains unaltered, it follows that at a greater speed the air in the cylinder is more rarefied, and consequently less air is drawn into the cylinder per stroke. As that air is drawn through the mixture pipe at a greater velocity, more petrol is carried with it, so that the mixture becomes rapidly too strong as the engine speed increases, and, for the same reason, too weak as the speed decreases.

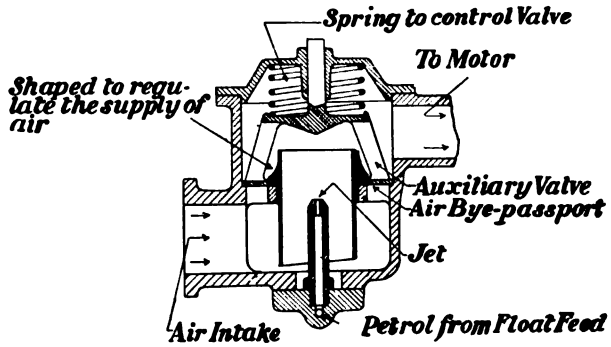

FIG. 2.—SIDDELEY EQUALISER.

The difference of air pressure between the float chamber and the jet chamber also forces some additional petrol through the jet, and the mixture is thus made still worse as the difference of pressure varies with the engine speed.

Most engines are now regulated by a throttle valve in the mixture pipe, between the carburettor and the induction valve. This controls the quantity of gas supplied to the engine, and the effect of partly closing the throttle is to reduce the velocity of air past the jet, the effect on the carburettor being the same as if the engine speed had been reduced.

If the throttle is nearly closed, to run the engine slowly without load, very little mixture is required; consequently the air flows past the jet with a very small velocity, and frequently draws insufficient petrol to form an explosive mixture.

From a consideration of the conditions it is found that, for a flexible engine, some addition must be made to the Maybach carburettor, to regulate the proportions of the parts to suit varying engine speeds, so that the engine may run fast economically and slow efficiently: to be satisfactory, this regulation should be automatic. The ideal motor car engine must be capable of being run either fast or slow with light or heavy loads, and to enable this to be done satisfactorily the explosive mixture should be of the same composition under all conditions.

THE first practical carburettor in which an attempt was made to fulfil the necessary conditions was brought out by Commandant Krebs, and is now largely used, being known as the "Krebs carburettor." In this carburettor (Fig. 3) the "Maybach" float and jet are retained, but the air intake is made of reduced size, so as to give a correct mixture at low speeds.

Automatic Carburettors

An auxiliary air port is placed in connection with the mixture pipe, this port being fitted with a piston valve controlled by the suction on a diaphragm, the suction being produced by the vacuum in the mixture pipe. As the engine speed increases, the increased vacuum draws down the diaphragm, which opens the auxiliary air port and dilutes the mixture, which is of course too strong, to the correct proportions.

The air port is so proportioned that the correct amount of additional air is introduced in ratio to the excess of strength of the original mixture, at whatever speed the engine may be running.

The diaphragm is controlled and prevented from sudden movements or "hunting" by the chamber above it forming a dashpot.

Most motor car engines are fitted with

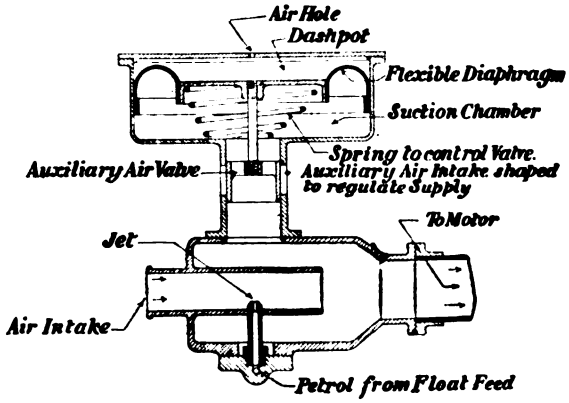

FIG. 3.—KREBS CARBURETTOR.

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some device to partly equalise the strength of the mixture, but many of them are exceedingly crude. That most frequently met with is a small valve in the mixture pipe, which opens and admits more air as the vacuum increases. This is better than nothing, and more nearly approaches the ideal than the "Maybach" carburettor, but does not admit additional air in the correct proportion to keep the composition of the mixture uniform under various conditions.

A device recently introduced is worthy of notice. This is the "equaliser" (Fig. 2) fitted to the carburettors of the new Siddeley cars. An annular valve surrounds the jet chamber, and is so arranged as to be lifted by the suction in the mixture pipe. The valve is held on its seat by a spring so arranged that the "lift" of the valve is proportional to the vacuum.

The curved face of the valve seat is of such a form as to allow air to be admitted in accordance with the requirements of the motor.

This carburettor attains the same result as the "Krebs," but is much simpler and less liable to get deranged. It will be noticed that with this arrangement all the air is drawn through the same intake, so that if warm air be used, as in the case of alcohol as fuel, the mixture is not chilled by the subsequent addition of cold air.

An Up-to-date Friction Clutch

THE usefulness of friction clutches, in connection with power distribution schemes which utilise shafting, is too well recognised to need more than cursory mention here. A good friction clutch should possess the following characteristics: — It should be self-contained, and comprise no loose parts which can clatter in running. It should hold firmly when in gear, be easily released, and give perfect freedom when out of gear. There should be no end-thrust, and for high-speed transmission the balance should be as perfect as possible. It should be easily adjusted, even when the machinery is running; and it should produce no shock or jar when thrown in or out of gear. The clutch should also be as simple in construction as possible, and adequate provision should be made for lubrication. All of these conditions are complied with by Heywood and Bridges Improved Patent Friction Clutch, illustrated in Figs. 4 to 6. The principle of the clutch can be readily understood by reference to Fig. 4, which shows an end view, and a transverse section of the clutch. Keyed on to the driving shaft A is a boss B, cast in a piece with the two arms C,C, and the rim D,D. The rim is divided at E,E, each half being connected to the end of only

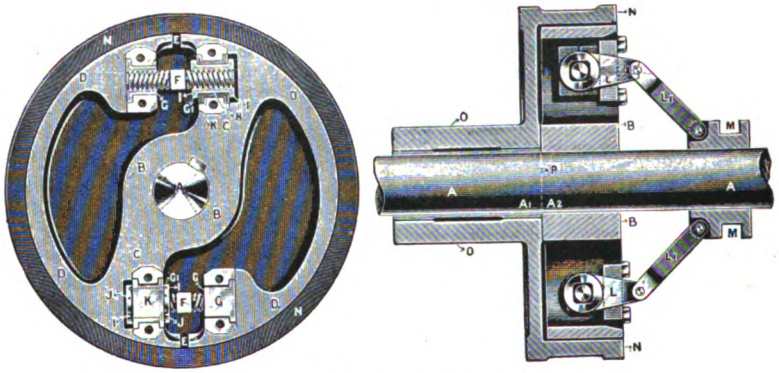

FIG. 4.—HEYWOOD AND BRIDGES FRICTION CLUTCH.

one of the radial arms C,C. The clearance between the rim D,D, and the external shell N is such that the two are normally out of contact; but the rim D,D can be caused to expand by means of the right- and left-handed screws F,F, in which case the shell N becomes forced to rotate with the shaft A. The screws F,F are actuated by levers L,L_1 (Fig. 4), connected to the sliding sleeve M. The sockets G,G_1 are cast in the rim D; in them are placed adjustable round nuts H, flanged at I, and provided with "tommy" holes J. The nuts H are carried in square blocks K formed in halves, with a slight clearance between the two portions. It is easily seen that the clutch will be thrown into gear when the sliding sleeve M is forced up toward the face of the clutch, and that it will be released when the sleeve M is moved in an opposite direction.

Fig. 5 shows a friction clutch applied to

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a grooved pulley. Several different methods of lubrication may be adopted, according to requirements. To keep the gun-metal bush A lubricated, three oil inlet holes, B, are drilled and tapped, at equal distances from each other, in the circumference of the boss C, and fitted with $\frac{3}{8}$-in. gas plugs; the bush is grooved to form the cavity D, which is periodically filled with the best oil. Sometimes it is of advantage to apply the automatic "greaseoline" lubricators F,F, in which case the lubricant is periodically forced into the space between bush and shaft by turning the head of the lubricator by hand. When the clutch is placed at the end of a shaft, the latter is drilled up the centre H to the bush, and fitted with an automatic lubricator.

It is advisable to occasionally apply a little sperm oil to the right- and left-handed screws

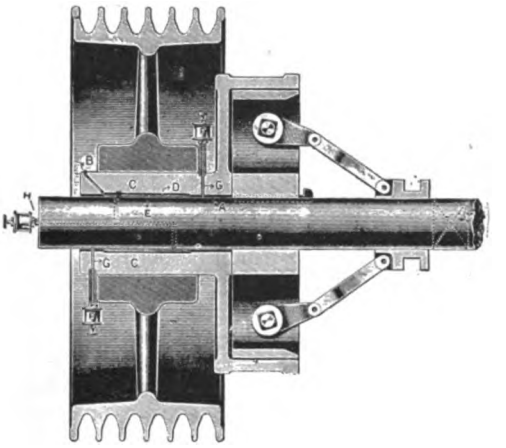

FIG. 5.—FRICTION CLUTCH APPLIED TO GROOVED PULLEY.

F,F (Fig. 4). When the clutch is not in constant use, a little oil should be periodically run between the frictional surfaces; if slipping occurs on subsequently using the clutch, a little naphtha, turpentine, or caustic soda applied to the surfaces will remove this source of trouble, provided the clutch does not require adjusting. The clutch is adjusted by the aid of the tommy holes J,J. Fig. 6 shows a clutch provided with dovetailed hardwood lags fitted in the internal part of the clutch; this arrangement is suitable for working in wet places. The lags can be renewed without taking the clutch off the shaft; by their aid the life of the clutch is considerably enhanced.

THE recent researches of M. Paul Sabatier, of the University of Toulouse, and his assistants as to the effect of catalytic agents upon various compounds of carbon are of considerable value. The effect as to the oxides of carbon had (although unpublished) been anticipated in a large measure by Mr. H. S. Elworthy in his investigations, which resulted in his patent (No. 12461 of 1902) for the manufacture of methane. This priority was recognised in the granting to Mr. Elworthy of his German patent, after inquiry by the officials of the German Government. This example of two investigators working on parallel lines, unknown to each other, does credit to both gentlemen alike, and their fundamental data may probably issue in large scale plant being erected both in this country and in France.

Hydrogenation of Carbon Compounds

M. Sabatier states, that when he tried the

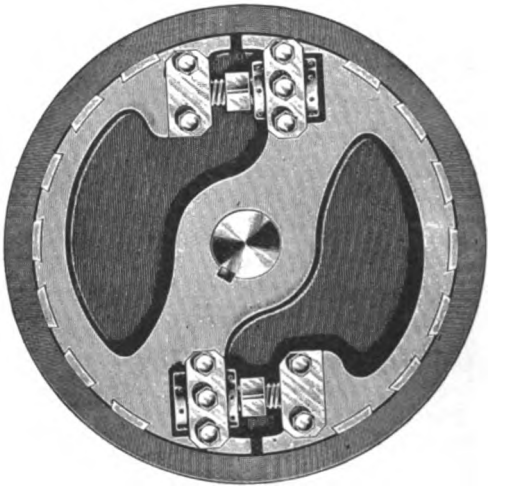

FIG. 6.—FRICTION CLUTCH WITH WOODEN LAGS.

action of heated nickel, cobalt, and iron, in powder, on carbon monoxide, he found with nickel and cobalt a catalytic decomposition of the gas. The superiority of reduced nickel as a catalyst was also shown in the experiments on aldehydes and ketones; for whereas reduced cobalt acts less energetically and the yield is smaller, reduced copper only acts on these compounds at a higher temperature, and platinum sponge acts so slowly and is so incomplete that the hydrogenation is of little practical utility.

It was found also that reduced nickel was effective in securing the hydrogenation of ethylene (C_2H_4), acetylene (C_2H_2), and of benzene (C_6H_6).

The first-named occurs at 300° C.

$$C_2H_4 + H_2 = C_2H_6 \text{ (ethane).}$$

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The second-named could be made to yield liquid hydro-carbons corresponding to those contained in American or Caucasian petroleum by varying the temperatures and conditions of the experiment. Hexane (C_6H_{14}) is typical of American oil composed chiefly of paraffins; and cyclo-hexane (C_6H_{12}) or hexamethylene $(CH_2)_6$ is typical of Caucasian oil composed chiefly of naphthenes.

The third-named, benzene, (C_6H_6), which may be polymerised from acetylene, was converted into C_6H_{12} (cyclo-hexane) when passed with hydrogen over reduced nickel at a comparatively low temperature. When the vapour of this naphthene was passed over the same catalyst at 270° to 280° it gave benzene and methane :—

(*a*) $3\ C_6H_6 + 9\ H_2 = 3\ C_6H_{12}$

(*b*) $3\ C_6H_{12} = 2\ C_6H_6 + 6\ CH_4$.

The result of the two reactions is the conversion of one-third of the benzene into six times its volume of marsh-gas. Such a result does not at the moment appear to have any technical value, the more useful conversion being that of carbon monoxide, dioxide, and hydrogen, ingredients which are much cheaper than benzene.

(*c*) At 200° to 250° C.,

$$CO + 3H_2 = CH_4 + H_2O.$$

(*d*) At 230° to 300° C.,

$$CO_2 + 4H_2 = CH_4 + 2H_2O.$$

These reactions (*c*) and (*d*) are the basis of Elworthy's process, and their value consists in producing, with a certain loss of total heat-units, a concentrated gaseous fuel, which develops in a luminous flame the lighting power of the higher hydrocarbous gases, of coal-gas or carburetted water-gas. The cost of making uncarburetted water-gas is small, and is accomplished by passing superheated steam over incandescent coke. In this case, $C + H_2O = CO + H_2$, the reaction being stopped when CO_2 begins to be formed to the extent of more than 5 per cent. of the mixture.

The proportion of hydrogen in this mixture is not sufficient for the reactions (*c*) and (*d*), and must receive twice its content from some other source, such as the well-known action of steam on heated iron. The mixed gases, in the proportion of three or four volumes of H to one of CO and one of CO_2, are passed over heated, finely divided nickel with condensation of volume as shown in the equations (*c*) and (*d*). The resulting marsh-gas yields a flame temperature in air of 4430° F., whilst CO and H yield 5530° and 4830° respectively; nevertheless, Professor Percy Frankland has found that the luminosity of coal gas is increased when it is diluted with marsh-gas. As a diluent, carbon monoxide is worst and marsh-gas best. In reducing the toxic effect of water-gas the substitution of methane for the carbon monoxide would be a decided improvement, even if a commercial success was obtained by a limited conversion, say, of 60 to 80 per cent. The action of the reduced nickel has not yet been explained, but it is believed that nickel carbonyl is an intermediate product. The nickel appears to be maintained without loss, and its activity may be restored by oxidation and a fresh reduction. Nickel carbonyl is the compound that plays the chief part in Mond's process of manufacturing the metal, and its properties, investigated by Langer, have been extended by Dewar and Jones (Proceedings Royal Society 1903, and Chemical Society 1902, p. 207). In this process CO unites with nickel at 50° to 100° C. to form nickel carbonyl $Ni(CO)_4$, which is dissociated at 180°–200° C. The heating value of methane is 1023 B. Th. units, as against 600 for coal-gas, each stated per cubic foot; and as the calorific power—as distinguished from intensity—of towns' gas is now the most important factor, there appears a favourable opportunity for the use of methane. Its prospects now depend upon the cost of production, when made upon the large scale.

The Chemistry of Castor Oil

"RICININE," obtained from castor-oil seeds in 1864, has since been a subject of controversy. A satisfactory study of this body has now been made by S. Philippe and L. Maguerine. They show that ricinine is probably the carboxyl derivative of an iminomethyl pyridine. (Comp. rend 138, 506.)

Automobile Design

A POINT in connection with the recent Gordon-Bennett motor race, showing the tendency of design, is the fact that the first five cars to finish were fitted with low-tension magneto ignition, by which the motor generates its own current for the electric ignition, and has a "make and break" inside the cylinder to cause the spark. The old style of using accumulators and an induction coil to give a high-tension spark jumping a gap, is being rapidly superseded by the low-tension magneto system, which system is also finding favour with designers of stationary gas and oil engines.

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THE MECHANICS OF HEAVY ELECTRIC TRACTION.

By H. F. PARSHALL, M.I.C.E., M.I.E.E., and H. M. HOBART, M.I.E.E.

THERE is a general impression that the subject of tractive effort on rails is but little understood. Although this is to a certain extent the case so far as relates to an analysis of the various physical causes of resistance to motion on rails, there is now fairly general agreement as to the amount of the total tractive resistance at various speeds on a modern well-built surface railway, on a calm day, on a straight track. While there are minds to which an indefiniteness of the nature of 20 per cent. presents itself as a hopeless impediment, there appears to be no justification for this attitude so far as relates to tractive resistance on rails. It is true that the degree of wetness or dryness of the rail, the velocity of the wind, the contour of the train and its mechanical design, and the character of the permanent way, all introduce considerable variations. The engineer will not disregard these influences; indeed, each of these influences will, in a given case, require careful study. But so far as relates to preliminary estimates of the average power required at the axles, the most elaborate recent experimental data obtained in different countries and under very varied conditions, converge toward sufficiently definite values.

As a matter of fact, even were the latest experimental data for tractive effort at various speeds widely divergent, no considerable uncertainty would be introduced into the results, except for the case of long runs between stops. For runs of lengths up to a mile or two at high schedule speeds, the energy consumed during the accelerating interval is so considerable a percentage of the total energy consumption, as to mask very great inaccuracies in the data of tractive effort at constant speed. The calculation of the energy consumed during the accelerating interval is much more independent of assumptions based on experimental data. The shorter the run between stops, the greater is the importance of accuracy in estimations affecting the acceleration period, while the estimations of the frictional resistance are of comparatively little account. The longer the run between stops, the more important does it become to base the estimations upon fairly correct data of tractive resistance.

Train Resistance at Starting.

The train resistance at starting on a level is very dependent upon the type and design of the bearings, the wheel diameter, and the design and condition of the permanent way. Aspinall's value of seventeen pounds per ton is a fair average figure for the best conditions obtaining on main lines with medium and heavy trains. On the Central London Tube Railway, the starting resistance on the level is twenty pounds per ton for a 113-ton train comprising seven cars. On the City and South London tube railway, McMahon's experiments showed a starting resistance of forty pounds per ton for 26-ton trains.* This value is rarely exceeded, even on urban tramway lines.

Train Resistance at Uniform Speed.

For heavy electric traction, speeds of less than ten miles per hour rarely require to be considered. From ten miles to one hundred miles per hour the following formula, due to Aspinall, leads to very trustworthy results:—

$$R = 2{\cdot}5 + \frac{V^{\frac{5}{3}} \dagger}{51 + 0{\cdot}028\,L}$$

R = Tractive resistance in pounds per (metric) ton (of 2,200 lbs. or 1,000 kgs.).
V = Speed in miles per hour.
L = Length of train in feet.

* "The curve showed the variation in the drawbar pull, its high value at the start, about 40 lbs. per ton, dropping to the minimum of 9 lbs. per ton. . . . The most striking feature of it was the high resistance at starting, and in order to test that an experiment had been made with the train in a siding, a spring balance being used to start it very slowly; the resistance in that case had been found to be 20 lbs. to 25 lbs. per ton. A similar experiment on a locomotive had shown the resistance to be 25 lbs. to 30 lbs. per ton, but the first test when the locomotive was standing had always given a higher result, and that seemed to be due to the squeezing out of the oil."—McMahon, Proceedings of the Institution of Civil Engineers (1901), Vol. CXLVII., p. 213.

Moreover, McMahon's wheel diameters were but 24".

† Values of $V^{\frac{5}{3}}$ are given in Table I.

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TABLE I.

V Speed in Miles per Hour.	$V^{\frac{1}{2}}$	
10	46·77 or	46·8 (nearly)
15	74·43 ,,	74·4 ,,
20	151·4 ,,	151 ,,
25	213·8 ,,	214 ,,
30	295·1 ,,	295 ,,
40	473·2 ,,	473 ,,
50	676·1 ,,	676 ,,
60	933·3 ,,	933 ,,
70	1175 ,,	1180 ,,
80	1514 ,,	1510 ,,
90	1820 ,,	1820 ,,
100	2160 ,,	2160 ,,
120	2818 ,,	2820 ,,

The formula, owing to the fractional exponential power of V, is an inconvenient one to use, and hence the curves of Fig. 1 have been prepared for train lengths of 100, 1,000, and 2,000 feet, which cover most cases which will occur in heavy electric traction.*

Now while it is quite true that these results vary from the results of other careful investigations, sometimes by high percentages, this is really of minor importance, on account of numerous other uncontrollable factors. Thus in a heavy wind the train resistance will often be doubled. Variation in the type and condition of the rail,† the condition of permanent way, type of rolling stock, etc., also introduce great differences in the train resistance, as also the location of the driving power, whether distributed upon the axles of the different vehicles, or concentrated on a locomotive. These and similar considerations lead to the conclusion that the results set forth in the curves of Fig. 1 are amply precise as a basis for calculations.

The recent high-speed tests at Zossen, near Berlin, included elaborate determinations of the tractive resistance. These tests were made upon single coaches of a length of seventy-six feet and weighing eighty-three tons; the design, chiefly on account of the great capacity of the motor equipment, thus having the exceptional constant of 1·10 tons weight per foot of overall length.‡ The results obtained from these tests are given in the lower curve of Fig. 2, and the results calculated from Aspinall's formula are given in the upper curve of the same figure. The agreement is seen to be excellent. But for this excellent agreement between the Aspinall and the Zossen tests, both of which were most elaborate, the values at the lower speeds would have been

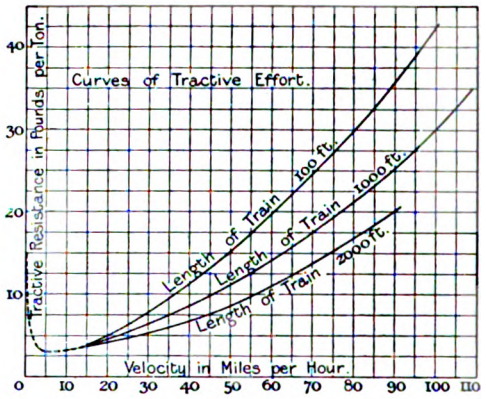

FIG. 1.

pronounced decidedly too low, as all prior formulæ gave higher results at low speeds. That this is the case is evident from Figs. 3 and 4, taken from Gottshall's "Electric Railway Economics" (pp. 156 and 154).

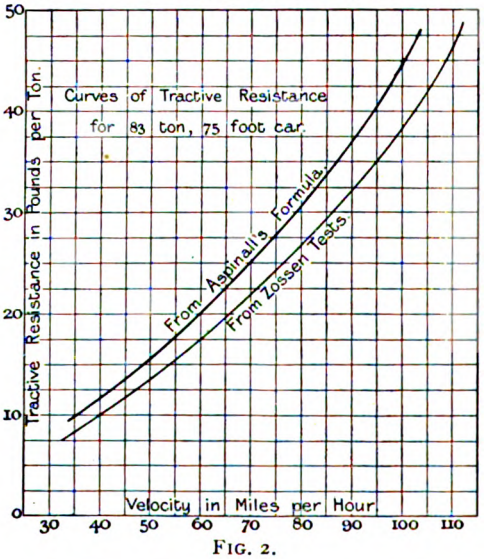

FIG. 2.

* "On the New York Central and Hudson River Railroad there were several trains daily of 3,000 tons to 4,000 tons, drawn by American locomotives, the number of cars ranging from 75 to 90."—Dudley, Proceedings of the Institution of Civil Engineers (1901), Vol. CXLVII., p. 261.

† "Dr. P. H. Dudley has stated that when he substituted an 80-lb. rail for a worn 65-lb. rail, it made a difference of 75 h.p. to 100 h.p., and he estimated that a 105-lb. rail saved 200 h.p., as compared with the 60-lb. or 65-lb. rail."—Aspinall, Proceedings of the Institution of Civil Engineers (1901), Vol. CXLVII., p. 241.

‡ In present practice on steam and electric railways, the weight of loaded car or train per foot of overall length rarely exceeds 0·65 tons, and as a rough but representative value 0·5 tons per foot of overall length may be taken. (*See* also Table II., p. 328.)

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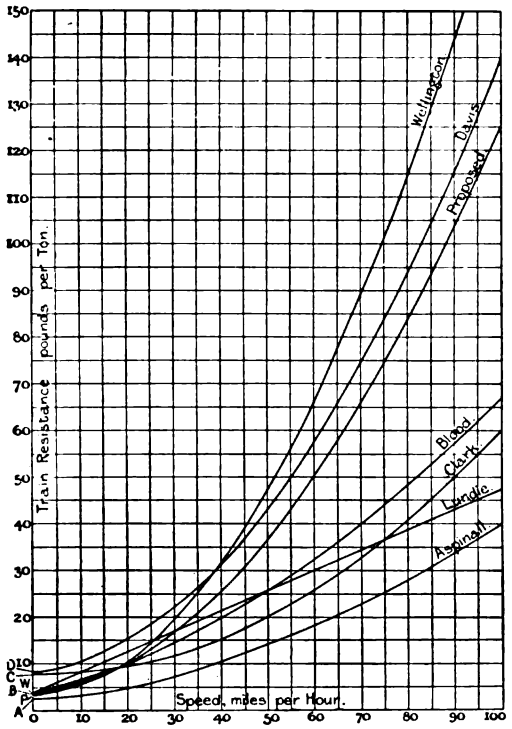

FIG. 3.—CURVES FOR TRAIN RESISTANCE, ACCORDING TO WELL-KNOWN FORMULÆ.
Single-Car Operation. Weight of car about 25 tons.

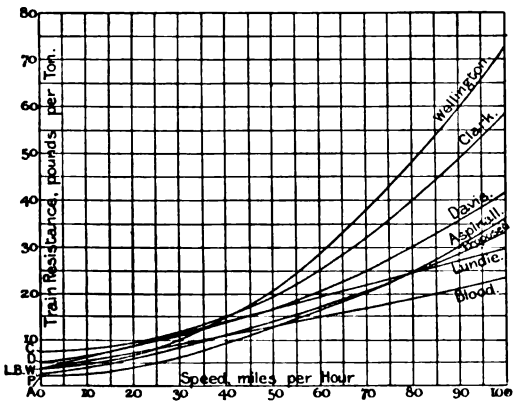

FIG. 4.—Same as Fig. 3, but for train of five carriages, say 225 tons.

In tube railways, where there is small clearance between the walls and the train, higher resistance (depending on the amount of clearance) has been found, varying as a function of the speed. In Fig. 5 are given curves deduced from tests on the Central London Railway (in which the tube's internal diameter is 11 ft. 6 in.), showing the train resistance as a function of the speed. The minimum clearance between the tube and train is 6 in.

From measurements made on the City and South London Railway, P. W. McMahon obtained the data from which the broken line curve of Fig. 5 has been deduced.

From the train test curves obtained on the Central London Railway, the total tractive effort at thirty miles an hour is 1,200 lbs. for a seven-car train, and 600 lbs. for a single

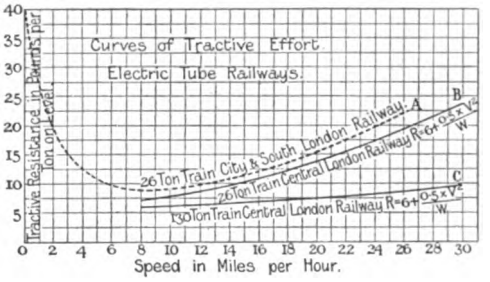
Curves of Tractive Effort
Electric Tube Railways.
Tractive Resistance in Pounds per Ton on Level.
Speed in Miles per Hour.
26 Ton Train City & South London Railway.
26 Ton Train Central London Railway R=6+0.5×V²/W
130 Ton Train Central London Railway R=6+0.5×V²/W

FIG. 5.

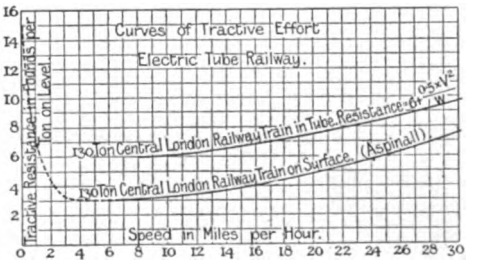
Curves of Tractive Effort
Electric Tube Railway.
Tractive Resistance in Pounds per Ton on Level.
Speed in Miles per Hour.
130 Ton Central London Railway Train in Tube. Resistance=6+0.5×V²/W
130 Ton Central London Railway Train on Surface. (Aspinall).

FIG. 6.

car. The weights of the trains being 125 tons and 25 tons respectively, it appears that there is a constant figure of 6 lbs. per ton for journal friction, etc., and a figure for the head and tail resistance which depends upon the speed and is unaffected by the length of the train, the actual equation for the total tractive resistance being:—

$$\text{Resistance in lbs. per ton} = 6 + 0{\cdot}5\,\frac{V^2}{W}$$

where V is the speed in miles per hour and W is the weight of the train in tons.

In Fig. 6 are two curves, one showing the resistance in lbs. per ton for a seven-car Central London train, as worked out by the above formula, and the other showing the resistance of this train on a surface track, as worked out by Aspinall's formula.

No tests have been made with high-speed service in such tube railways, but the resistance can be reasonably expected to be enormously increased at speeds above, say,

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forty miles per hour. Thus from the Zossen tests on an eighty-three-ton car it has been found that at a speed of forty miles per hour the air resistance becomes equal to the mechanical resistance; and at a speed of one hundred miles per hour the air resistance on surface roads is four times the mechanical resistance. This is seen from the curves of Fig. 7, in which the curve of total resistance for the Zossen tests is supplemented by two curves of the component resistances due respectively to air resistance and mechanical resistance. The longer the train, however,

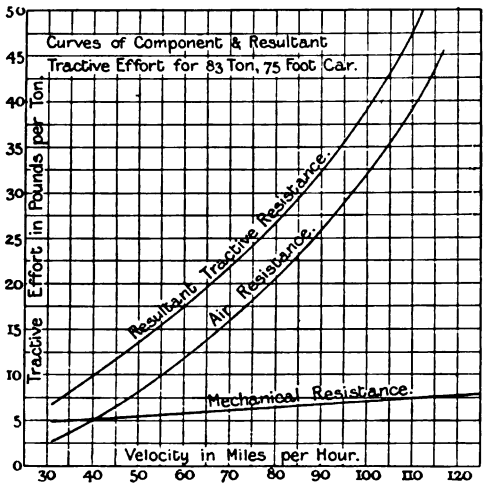

FIG. 7.

the less is the percentage which the air resistance constitutes of the total resistance; and for well-vestibuled trains of several hundred tons weight, the air resistance would probably not exceed the mechanical resistance below speeds of from forty-five to fifty miles per hour. For a five-coach train, Aspinall (Proceed. Inst. C.E., 1901, Vol. cxlvii, p. 249) estimates the atmospheric resistance as becoming equal to 50 per cent. of the total resistance at eighty miles per hour. But all his statements relate to the train behind the engine, and the engine shields the train from a considerable portion of the air resistance. Thus for a motor-car train, the air resistance would become equal to the mechanical resistances at a much lower speed, and the corresponding speed would be lower the shorter the train.

From such results it is evident that for high-speed work it would be futile to attempt to materially reduce the train resistance by modifications in the design of the rolling stock and permanent way,* and that attention should rather be directed to the contour of the train. Not only does the form of the front and rear ends greatly affect the air resistance, but when a train is composed of many vehicles, it must, so far as practicable, present continuous unbroken surfaces from end to end.†

Curves materially increase the train resistance, not only at low but at high speeds. At moderate speeds, measurements have often shown 100 per cent. increase in the train resistance, even on well-designed curves of fairly large radius. ‡

Heavily loaded trains have a resistance considerably lower (as expressed in pounds per ton) than light trains.§ This consideration is of importance chiefly in freight service, since

* Of course the greatest attention must, nevertheless, be given to the design of the rolling-stock and permanent way, in order to render high speeds practicable and satisfactory, and to exempt these parts from rapid deterioration; but so far as relates to obtaining the most economical result for tractive effort in pounds per ton at high speeds, the chief attention should be given to the contour of the individual carriages and of the train as a whole.

† ". . . . at high speeds the air resistance is by far the most important factor, and that the proper shape of the car has to be very carefully determined." —Siemens, Proceedings of the Institution of Electrical Engineers, May 26 (1904).

"Attention must also be paid to those details of design which will reduce the train resistance, and more especially that element thereof known as '*wind resistance*,' which is by far the greatest component of train resistance. Smooth, flat sides, with the platform ends rounded or tapered, and enclosed, are among the simple and effective methods employed. It is astonishing what a saving in watt-hours per ton mile, or per car mile, the application of the simple methods above suggested will produce, as indicated by recent tests."—Gottshall "Electric Railway Economics," p. 152

‡ "An attempt had also been made to determine the effect of curves on the tractive resistance, but it had been found to be very difficult to do so on account of the curves on the line being so short. The results of three tests on a curve having a radius of 390 feet gave 27·9 lbs. per ton at 16·5 miles per hour, whereas on the straight road the result was 12¾ lbs. per ton, leaving about 15 lbs. per ton due to the curve alone. Six experiments had been made on a curve of 540 feet radius, giving 22·6 lbs. per ton at 13½ miles per hour, whereas on the level it was 11·3 lbs. per ton, leaving 11·3 lbs. per ton due to the curve."—McMahon, Proceedings of the Institution of Civil Engineers, (1901), Vol CXLVII., p. 215.

§ "With a train of empty wagons 1,830 feet long, the resistance had been found to be 18·3 lbs. per ton at a speed of 26 miles per hour; a train of full wagons 1,045 feet long had given 9·1 lbs. per ton at 29 miles per hour; and another of the same length, as low a figure as 6·2 lbs. per ton at 28 miles per hour. He trusted, however, that these figures would not be regarded as results which could be finally established without further proof."—Aspinall, Proceedings of the Institution of Civil Engineers (1901), Vol. CXLVII., p. 197

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in passenger service the weight of the passengers is but an inconsiderable percentage of the weight of the train in which they travel, *i.e.*, whereas the goods transported constitute the greater part of the weight of the train in freight service, the passengers transported, including their luggage, rarely constitute much more than 10 per cent. of the total weight of the train. From the statement that heavily loaded trains have a resistance considerably lower as expressed in pounds per ton (*i.e.*, a lower "specific resistance") than light trains, it might naturally be concluded that locomotives, which have a far higher weight in proportion to their length than the carriages they haul, would require a less tractive effort per ton of weight for a given speed. This is, however, not the case. Although in steam practice, with a passenger train having a total weight of 300 tons, the locomotive would weigh but 75 to 100 tons, or 25 per cent. to 33 per cent. of the total weight; from 35 per cent. to 55 per cent. of the power indicated by the locomotive would be employed in the losses in the locomotive and in the power required to propel it, thus leaving but from 45 per cent. to 65 per cent. of the indicated power available for propelling the rest of the train.* Incidentally this is an important fact to keep in mind in comparing the relative merits of traction by steam and electricity. In short trains the percentage of the energy employed for the locomotive itself is still higher.

As an interesting instance of the small percentage which the live load constitutes, in through and in suburban service respectively, there are given in Fig. 8 some curves applying to the conditions on the section of the New York Central and Hudson River Railway between the Grand Central Station in New York City and Mott Haven Junction. This is taken from a paper by Arnold published on page 876 of Vol. XIX. of the Transactions of the American Institute of Electrical Engineers.†

The direction and intensity of the wind may enormously increase or decrease the tractive effort required of the steam locomotive or of the electric motors, and this again is considerably dependent upon the design of the train as regards the contour of the front and rear ends, the vestibuling and other details. Curves also exert a great but practically unpredeterminable influence. The influence of gradients is readily determined by the principles of ordinary mechanics, and is equivalent to a positive or negative tractive effort of 22 lbs. per ton for a one per cent. gradient.

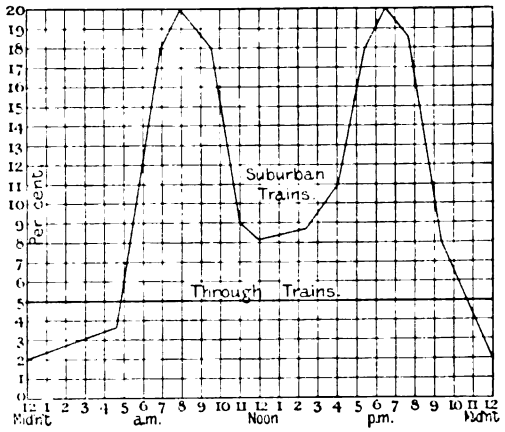

FIG. 8.—PERCENTAGE OF PASSENGER WEIGHT TO TRAIN WEIGHT, GRAND CENTRAL STATION TO MOTT HAVEN JUNCTION.

While all these points require attention in specific cases, one must have some simple basis for the further preliminary study of the mechanics of heavy electric traction. The curves of Fig. 1 will be taken as the ultimate basis for this preliminary study.

Although the length of the train and the weight in tons per foot of overall length

* "In order to see how much power the locomotive absorbed, as compared with the train, a certain number of experiments had been tried on the Lancashire and Yorkshire Railway, and it had been found that the ten-wheeled engine (No. 1392) absorbed 34 per cent. of the total horse power. Mr. W. M. Smith (Proceedings of the Institution of Mechanical Engineers, 1898, p. 605) had given the results of his experiments, as about 36 per cent. of the total horse-power; and Mr. Druitt Halpin had stated (Proceedings of the Institution of Mechanical Engineers, 1889, p. 150) that the Eastern Railway of France had found that the engine absorbed 57 per cent. of the total horse-power developed; while Dr. P. H. Dudley gave it at 55·6 per cent., and Mr. Barbier at 48 per cent. Probably 34 per cent. or 36 per cent. was about the right percentage, the other figures being much too high; at any rate, the experiments referred to in the Paper rather pointed to that conclusion, though, of course, the actual figure depended on the load behind the engine."—Aspinall, Proceedings of the Institution of Civil Engineers, (1901), Vol. CXLVII., p. 197.

† "It has been pointed out that only from 15 to 20 per cent. of a fully loaded train consists of a paying load, and with an average load as carried throughout the day this percentage will be reduced to 10 per cent. or less—that is, nine-tenths of the energy consumed in moving this train at a constant speed is wasted."—Armstrong, Transactions of the American Institution of Electrical Engineers (1898), Vol. XV., p. 375.

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constitute the most correct basis for final reference, it is much more useful, even at some slight sacrifice of accuracy, to derive curves in which the length of the train in feet is replaced by the weight of the train in tons. For this purpose we must obtain representative figures for the weights of heavy single cars and of trains, per foot of overall length.

The examples given in Table II. are taken from present practice.

It is thus seen that one-half ton per foot of overall length is, *for the present purpose*, sufficiently representative of all except the most abnormal cases of rail traction. Since the curves of Fig. 1 show that the decrease in tractive effort per ton with increasing length of train is relatively slow, owing to the large constant term in the denominator of the second term, and the constant first term in the formula, we may rightly take this figure of one-half ton per foot length, in transforming the curves from length to weight. The curves given in Figs. 9 and 10 have thus been deduced for trains of a total weight of 50, 100, 200, 400, and 800 tons, and from this point we shall rarely refer back to the former curves, but shall base our study on the curves in Figs. 9 and 10. In Fig. 11 are given corresponding curves in which the kilowatts at the axles per ton weight of train are taken as ordinates, and the speed in miles per hour as abscissæ. In Fig. 12 the total kilowatts at the axles are plotted against the speed.

We have thus obtained values for the rate

TABLE II.

	Overall length in feet.	Loaded weight in metric tons.	Loaded weight in metric tons per foot of overall length.	Seats per foot.	Seats per ton.
Steam Railroad Standard Suburban Train made up of seven 8-wheeled coaches and locomotive (520 seats).	389	240	0·62	1·33	2·16
Great Northern and City continuous current motor-car train, 7 cars (422 seats).	355	195	0·55	1·19	2·16
Central London continuous current 7-car train (324 seats).	330	133·5	0·41	0·98	2·42
Mersey Railway continuous current train motor-cars (292 seats).	300	138	0·46	0·97	2·10
Manhattan Elevated Standard continuous current train made up of 4 motor-cars and 2 trailer-cars (286 seats).	282	125	0·44	1·01	2·29
Standard City and South London continuous current 4-car train with locomotive (128 seats).	141	41	0·35	0·91	3·12
Chicago and Joliet Interurban continuous current motor-car.	36	23	0·64	—	—
Burgdorf-Thun 3-phase motor-car (66 seats).	49	36	0·74	1·35	1·83
Zossen car, Siemens and Halske (48 seats).	76	83	1·10	·63	·58

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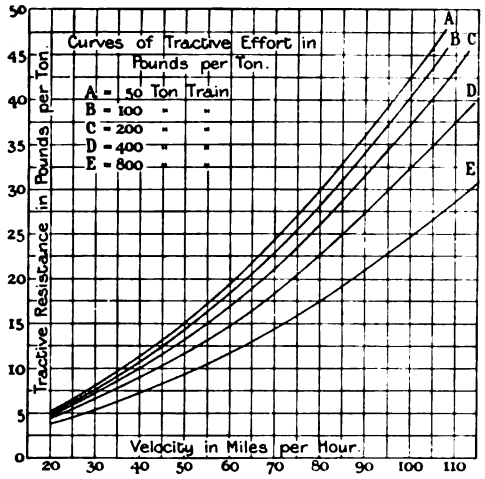
Curves of Tractive Effort in Pounds per Ton.
A = 50 Ton Train
B = 100 " "
C = 200 " "
D = 400 " "
E = 800 " "
Tractive Resistance in Pounds per Ton.
Velocity in Miles per Hour.

FIG. 9.

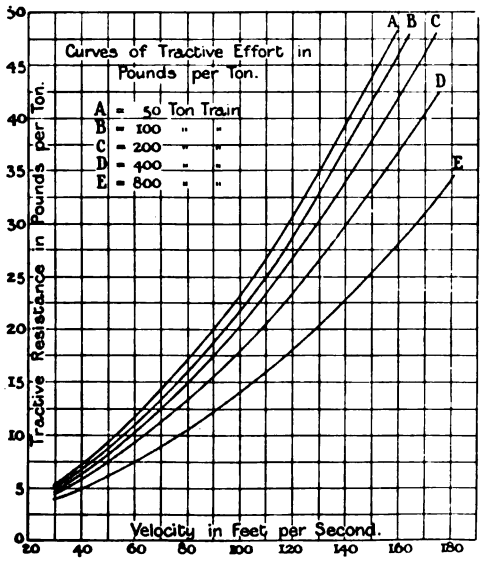
Curves of Tractive Effort in Pounds per Ton.
A = 50 Ton Train
B = 100 " "
C = 200 " "
D = 400 " "
E = 800 " "
Tractive Resistance in Pounds per Ton.
Velocity in Feet per Second.

FIG. 10.

of expenditure of energy required at the axles in moving the train along a well-ballasted, straight, level line at constant speed. This is, of course, a very different case from that generally met in practice. The chief difference is associated with the energy required for acceleration.

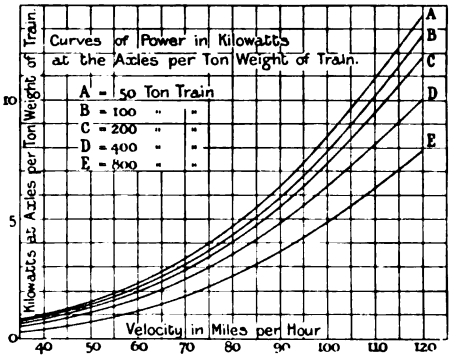
Curves of Power in Kilowatts at the Axles per Ton Weight of Train.
A = 50 Ton Train
B = 100 " "
C = 200 " "
D = 400 " "
E = 800 " "
Kilowatts at Axles per Ton Weight of Train.
Velocity in Miles per Hour

FIG. 11.

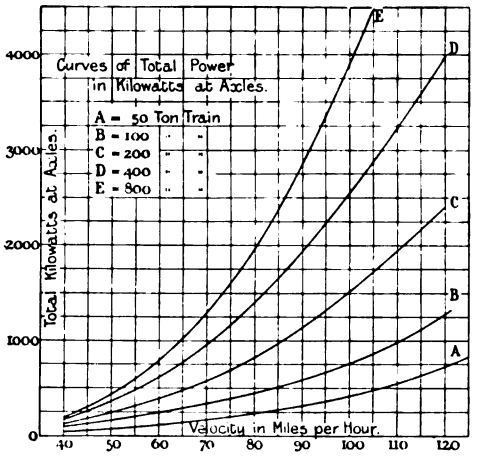
Curves of Total Power in Kilowatts at Axles.
A = 50 Ton Train
B = 100 " "
C = 200 " "
D = 400 " "
E = 800 " "
Total Kilowatts at Axles.
Velocity in Miles per Hour.

FIG. 12.

This accelerating energy, like the energy required for overcoming the tractive resistance, is customarily supplied to the axles by motors, and is subsequently wasted in braking. In some roads, however—such, for instance, as the Central London Railway—accelerating gradients contribute as much as one-fourth of the energy supplied to the train,* and similar retarding gradients assist the brakes at stopping.

* The *actual* energy supplied by the gradient is, of course, solely dependent on the height through which the train descends. On the Central London Railway the energy supplied by the gradients is about 14 watt-hours per ton mile, or about a quarter of the whole energy supplied to the train.

(*To be continued.*)

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THE INFLUENCE OF CASTING TEMPERATURE ON THE PROPERTIES OF METALS.

By PERCY LONGMUIR.

THE writer's earlier work* in this direction has conclusively shown that the mechanical properties of industrial brasses are in very large measure a function of casting temperature. For instance, the following table gives the results obtained from a series of three castings poured from one crucible, at selected temperatures of "hot," "fair," and "cold," the last one being well within the range of fluidity.

TABLE I.

Alloy.	Copper.	Zinc.	Maximum Stress Tons. per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.	Casting Temperature.
Red Brass	89·6	10·2	6·85	13·25	12·65	1308° C.
	89·6	10·2	12·64	26·00	30·28	1073° C.
	89·6	10·2	5·67	5·5	6·64	1058° C.

Very similar results may be obtained from any of the industrial brasses, provided a sufficiently wide range of temperature is selected. Thus, by starting with a high initial temperature and pouring a series of castings at successive intervals until solidification occurs, a wide variation in mechanical properties will be obtained. Many of these experiments have been made on a large variety of alloys, and in every case it has been found that tenacity and ductility rise with a falling casting temperature until the fair casting heat is reached, a further fall in temperature being accompanied by a corresponding fall in mechanical properties.

This variation in mechanical properties is also associated with a marked change in structure: the high-casting temperatures favouring a "loose" type of structure, the "fair" heats resulting in an "interlocked" structure, whilst the "low" heats favour a decidedly sharp type of crystallisation. These features are illustrated by the accompanying photo-micrographs: Fig. 1, showing the "loose" open structure of the high-casting temperature; Fig. 2, the interlocked or interwoven type familiar to the "fair" heat; and Fig. 3, the sharp crystallisation typical of low-casting temperatures.

The foregoing gives, in brief, a summary of work already published; in continuing the investigations several commercially pure metals have been examined and further confirmatory results obtained. These results are embodied in the following note, and represent hitherto unpublished matter.

The plan followed in each experiment was to considerably overheat a crucible of the metal in order to obtain the high casting temperature; the contents of the crucible were then allowed to cool down to the "fair" heat, and a further set of bars poured; still further cooling results in the "low" heat—a temperature at which the metal is just fluid. All the temperatures were measured by means of the Le Chatelier pyrometer. The metals zinc, copper and

FIG. 1.
PHOTO-MICROGRAPH OF GUN-METAL CAST AT HIGH TEMPERATURE
(*Magnified 58 diameters.*)

* *Journal of the Iron and Steel Institute*, 1903, No. 1, p. 457.

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aluminium are specially interesting, and some typical results are embodied in Table II. given below.

A casual glance at this table gives the impression that the variations are not nearly so marked as in the case of the alloys. It must, however, be remembered that the whole of the values are comparatively low; thus, in the case of a fragile metal like zinc the highest test recorded only represents a tenacity of 1·8 tons per square inch. Yet in this particular case a fall in casting temperature of only 37° C. is accompanied by a decrease in maximum stress equivalent to 986 pounds per square inch. The variations in the case of aluminium are chiefly shown on the extensibility of the metal. With the copper it will be noted that the highest maximum stress occurs in the lowest casting temperature; the greatest extensibility is, however, associated with the fair casting heat. Companion bars poured at the same temperatures, and subjected to equal after treatment, illustrate the survival of the influence of casting temperature. A reference to the annealed and quenched bars shows the actual results obtained, and it is noteworthy that, in the majority of cases, no form of after treatment eliminates defects due to faulty casting temperature. Certainly the metal or alloy may be improved by subsequent treatment, but its properties do not approach those of material cast at a normal temperature. Companion bars cast at different temperatures, and given equal after treatment, always maintain their relative characteristics, or, in other words, no matter how great the improvement in quality induced by the treatment, the original variations are still present.

TABLE II.

Metal.	No.	Casting Temperature.	Maximum Stress Tons per sq. in.	Elongation per cent. on 2 in.	Remarks.
Zinc	118	580° C.	1·30	—	All poured at intervals from one crucible.
	119	528° C.	1·81	—	
	120	491° C.	1·37	—	
Aluminium	121	725° C.	4·48	2·5	All from one crucible.
	122	691° C.	5·62	8·5	
	123	662° C.	5·12	5·0	
Copper	124	1500° C.	7·60	8·5	All from one crucible.
	125	1446° C.	7·80	11·0	
	126	1141° C.	8·80	8·0	
Copper	124A	—	4·52	8·0	Nos. 124A to 126A heated to 646° C. and cooled in air.
	125A	—	6·86	10·0	
	126A	—	8·51	8·0	
Copper	124Q	—	5·80	9·0	Nos. 124Q to 126Q heated to 543° and quenched.
	125Q	—	8·36	15·5	
	126Q	—	9·04	10·0	

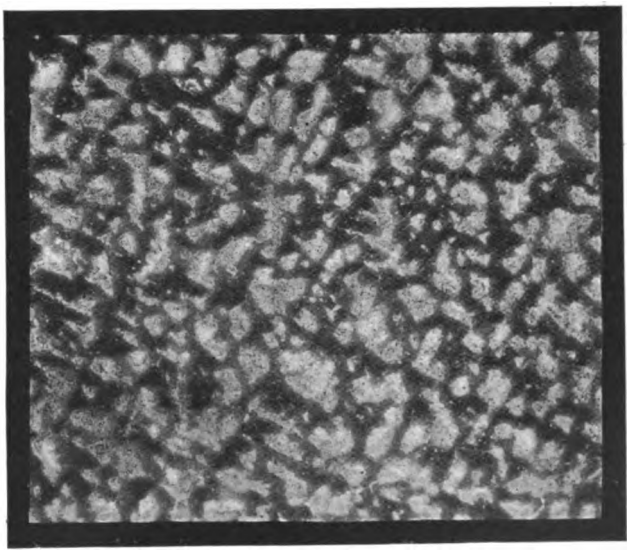

FIG. 2.—PHOTO-MICROGRAPH OF GUN-METAL, CAST AT "FAIR" TEMPERATURE.
(*Magnified 58 diameters.*)

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The only exception to this statement yet obtained has been found in the case of lead, and in this particular instance the restoration was an accidental effect. Preliminary experiments in which an exceptionally high initial casting temperature was obtained yielded an elongation of only $8\frac{1}{2}$ per cent., the bar showing many distinct cracks, and breaking quite short. A similar bar poured from the same crucible some four minutes later gave an elongation of 35 per cent. The fair casting heat also appears to be near the solidification point, for it is extremely difficult to obtain perfect castings typical of a low temperature, a feature explained by the absence of fluidity near the freezing point. In view of the results just quoted, the first three in the following table are singular, for they are very nearly uniform, notwithstanding fairly wide range in casting temperature. These particular bars were made some considerable time before testing, and in the interval were stored in a room at an unknown temperature,

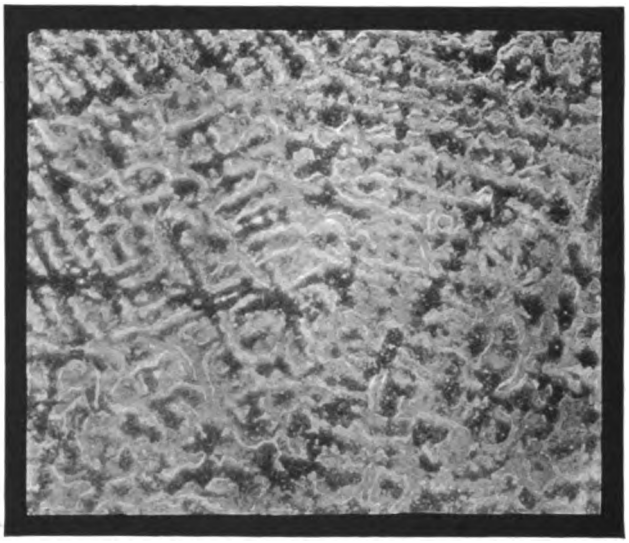

FIG. 3.—PHOTO-MICROGRAPH OF GUN-METAL, CAST AT LOW TEMPERATURE.
(Magnified 58 diameters.)

but one certainly above atmospheric. No microscopical work was attempted, but the tensile results apparently point to re-crystallisation, during which the three bars were brought into one uniform condition. The chief interest lies in the fact that, although many experiments have been made on a variety of alloys, this instance of lead is the only one in which the influence of casting temperature has been neutralised and the properties of the metal poured at three heats brought to one level.

Unfortunately, the exact period between casting and testing cannot be definitely given for the first three bars. The second three, numbers 130 to 132, were tested the day following, and the results given are typical of normal variations in casting temperature; much greater variations are obtained with wider ranges of temperature. The next three represent duplicate bars of numbers 130 to 132, tested some three months after casting. It will be noted that by this period of rest, the high temperature casting gains in ductility, as represented by an increase of 12 per cent. in extensibility, numbers 131 and 132 also gaining slightly.

TABLE III.—LEAD.

No.	Casting Temperature.	Maximum Stress Tons per sq. in.	Elongation per cent. on 2 in.	Remarks.
127	566° C.	1·70	40·0	Tested some time after casting.
128	426° C.	1·71	40·0	
129	356° C.	1·64	35·0	
130	580° C.	1·13	18·0	Tested the day following casting.
131	430° C.	1·43	35·0	
132	300° C.	1·30	42·0	
133	580° C.	1·44	30·0	Companion bars of 130, 131, and 132, tested 3 months after casting.
134	430° C.	1·46	37·5	
135	360° C.	1·46	46·5	
136	575° C.	1·41	20·0	Tested 6 days after casting.
137	450° C.	1·47	35·0	
138	370° C.	1·51	50·0	

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MANIPULATION OF CLAY APPLIED TO POTTERY FORMATION.

By WILTON P. RIX, late Manager of Messrs. Doulton's Art Pottery, Lambeth.

THE processes by which clay is made to take any required shape are based on the *properties* of the clays to be used, its *condition* at the time of formation, and the *shape* of the object to be produced.

These processes may be confined to one operation, or they may consist of a series. They may be accomplished by hand only, or by mechanical means, the tools and machines being actuated by motive or manual power.

Properties of Material

The properties of the clay requiring most consideration in deciding on the method of formation are :—

(*a*) Its *plasticity*, indicated by the capacity of ready movement of the clay particles over each other.

(*b*) Its *tenacity*, evinced in its capacity for stretching without breaking.

(*c*) Its *cohesion*, shown by the ease with which one portion can be joined to another and become soundly united.

All these qualities are usually included in the general term "plasticity," but the preponderance of one or more of them will greatly influence the potter in selecting his methods.

The ready movement of the particles over each other, which causes plasticity, is the cardinal quality in pottery formation. Clays possessing this quality in a high degree are most capable of being shaped without the use of tools or mechanical appliances.

Thus plastic clays are mostly used for hand modelling, and for throwing on the potter's wheel.

For the latter method, however, the clay also requires considerable *tenacity*, enabling the thrower to stretch the body outward in forming the "belly" of the shape.

The quality of *cohesion* is best exemplified in the soundness of ware which has been made in separate parts, and afterwards stuck together in the plastic state, such as spouts and handles of jugs, lugs on bowls, knobs on covers.

Condition of Material.

The conditions requisite for successful formation are :—

(*a*) *Homogeneousness*, enabling it to maintain uniform shrinkage in drying and firing.

(*b*) *Adequate humidity*, adapted to the method chosen.

As, in the forming of the shape, *plasticity* is the first requisite : so, in retaining it, *homogeneousness* is the chief consideration. Want of uniformity in the mixture of the particles or in the consistency of the mass causes one part to shrink more than another, and warping or cracking results.

The *humidity* or consistency of the clay is regulated partly by the proportion of non-plastic particles it contains, partly by the method of formation adopted.

Thus the greater the amount of non-plastic contents, the less the proportion of water required to bring it to a suitable condition.

Various methods, however, require differing proportions of water added to the clay for successful manipulation.

The consistency is usually described as follows :—

Slop.—A liquid condition, as used for casting pottery in plaster moulds.

Soft Mud.—The softest state in which the material will retain its form when removed from the mould immediately after making.

Soft Plastic.—The state in which the clay can most readily be pressed into moulds without adhering to the fingers.

Stiff Plastic.—Stiffer than the last condition, and requiring considerable pressure to put into form; hence chiefly used for mechanical pressing in metal moulds.

Semi-dry.—A condition in which the body is too dry to be compressed into a die without being first reduced to a state of damp dust. The pressure required is much greater and the particles only adhere at the point of contact.

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FIG. 1.—THROWINGS. "OPENING THE BALL."
(By permission of Messrs. York and Sons.)

METHODS OF FORMATION

The methods adopted in clay manipulation are dependent on the shape and the character of the material.

It is possible to form some goods by various methods, and choice will be determined by the quantity or quality of goods which can be produced.

The difficulties of production rest in dealing with quantity and ensuring adequate uniformity at a reasonable cost, rather than in obtaining single pieces of high quality.

Methods of shaping must therefore have in view always the readiest manipulation, compatible, if possible, with artistic embellishment by mechanical means.

The means of shaping the form for manufacturing purposes are as follows :—

(*a*) *Throwing.*—The form, which may be completed entirely by the hand, is revolved on a horizontal disc.

(*b*) *Jolleying.*—The exterior form is produced by pressing the clay against a rotating mould, the interior form being regulated by a forming tool or profile.

(*c*) *Moulding or Pressing.*—The exterior form is produced by pressing thin sheets of plastic clay by hand against the interior walls of a plaster mould of any given form, the interior form being usually regulated by smoothing with a sponge or leather.

(*d*) *Expression.*—The clay being placed in a metal chamber or cylinder, is caused, by means of a piston, to exude through an opening in the bottom of the cylinder, to which any desired section is given.

(*e*) *Plastic Compression.*—The clay is filled into a stout metal box, and is made to fill closely every part of the interior (thus taking its exact form) by the downward pressure of a plunger which exactly fills the orifice of the box.

(*f*) *Dust Compression.*—The form of the machine or press is similar to the last-named, but the box is filled by moist clay dust instead of plastic clay, and greater pressure is used.

(*g*) *Casting.*—The clay is filled into a dry plaster mould in a liquid state. The porosity of the plaster absorbs a certain portion of the water from the liquid clay adjacent to the mould, thereby causing the clay particles to become deposited, and to adhere to the mould. After a few minutes, the liquid residue is poured away, leaving the clay within. This hardens by evaporation, and shrinks away from the mould, which can finally be removed.

In moulding by jolley or by hand, it is usual to roughly shape the clay into form before inserting it in the mould.

When pressing by machine stiffer clay is used, as it gives greater resistance to the pressure, and takes more accurately the form of the box. The rough form is therefore made in soft clay, and stiffened before placing in the press.

FIG. 2.—THROWING. "KNUCKLING UP."
(By permission of Messrs. York and Sons.)

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It is also very usual to finish or "fettle" the edges and seams after leaving the mould or machine press.

The Potter's Wheel.

Of all appliances in pottery the "Thrower's Wheel" is the most ancient and the simplest. It consists merely of a horizontal disc supported on a vertical spindle capable of being rotated by hand, foot, or motive power.

It has for its object the rapid rotation of a clay mass made to adhere to the upper side of the disc or table, the clay being then shaped by the wet hands of the thrower.

The process is one of the simplest, yet most difficult, depending chiefly on the skill of the worker.

The hands alone form the shape, no tools being essential.

The wheel is first set in rapid motion, the ball of clay being thrown down in the centre to make it adhere.

The mass is then given a regular structure by drawing up and pressing down the ball as it yields to the pressure of the hands.

The operation of shaping then begins. The potter, enfolding the mass in his hands, puts his left thumb into the centre, and, first dipping his right hand in water, places both thumbs together points down, making the hole in the middle larger.

Having forced the low cylinder outward to the requisite diameter, he places the palms of both hands around the piece, and clasping the top edge with one thumb, forces it into a true form, at the same time using a gentle upward pressure with his palms. (See Fig. 1).

Fig. 3.—Throwing. "Shaping the Neck."
(By permission of Messrs. York and Sons.)

He now inserts one hand within the form, pressing the side of the forefinger against the lower part of the inner wall, and bringing the side of the forefinger of the other hand against the same spot on the outer wall, exerting a steady upward pressure as the clay slips between his fingers. At the same time the fingers are squeezed gently towards each other, making the walls thinner. This movement causes the cylinder of clay to elongate until the requisite height is attained. (See Fig. 2.)

Still keeping the hands and fingers in the same position, the thrower proceeds to give form and outline by forcing the sides of the cylinder more or less outward as the hands are drawn upwards.

The hands are then withdrawn, the palms are placed outside on the shoulder of the vessel, with the first and second fingers of the right hand overlapping the top edge.

This enables the mouth of the piece to be contracted, and the top edge to be forced into a true form (see Fig. 3).

The left palm is now placed within the mouth while the forefinger supports the outer wall, and by a gentle outward pressure the clay is caused to flow outward, completing the form required (see Fig. 4).

Fig. 4.—Throwing. "Finishing the Mouth."
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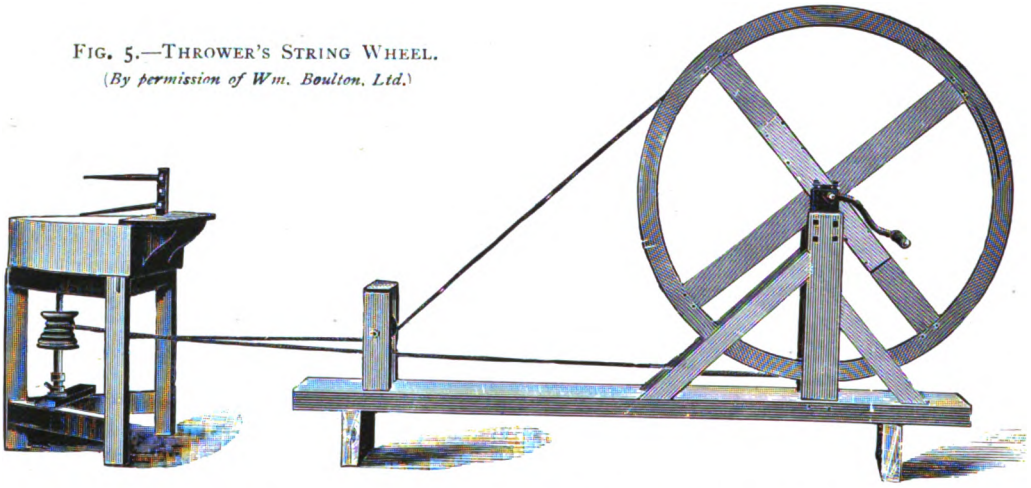

FIG. 5.—THROWER'S STRING WHEEL.
(By permission of Wm. Boulton, Ltd.)

The hands must be kept wet throughout the process to prevent friction: the structure must never be forced out of centre by undue pressure, otherwise the centrifugal force at once flings the mass off the wheel-head.

The forms of wheel are four in number:—

1. *The Foot Wheel*, actuated by the foot of the thrower on a lower disc fixed on the upright spindle. This is now seldom used.
2. *The String Wheel*, in which the motion is transmitted from a rope around a large fly-wheel turned by an assistant. This is used in factories which have no motive power (see Fig. 5).
3. *The Cogwheel.*—The gearing is fixed on the spindle of the wheel-head, and the crank turned by an assistant. This is chiefly used for throwing large vessels (see Fig. 6).
4. *The Friction Wheel.*—This is driven by power, the spindle being fitted with a friction cone which, by a pedal, is brought into contact with a similar cone fixed on the driving shaft. By an ingenious arrangement the cones can be made to touch at any given point, thus regulating the speed as desired (see Fig. 7).

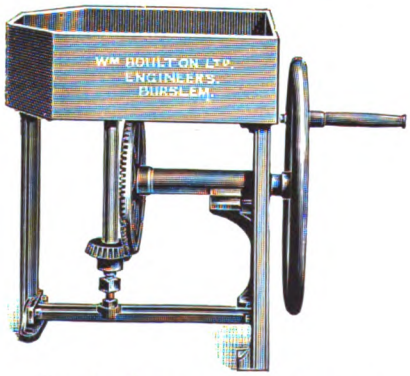

FIG. 6.—THROWER'S COG WHEEL.
(By permission of Wm. Boulton, Ltd.)

The tenacity of the clay is an element of great importance in thrown ware. Homogeneousness and absence of all grit is absolutely necessary. In order to ensure this, the clay, after being sifted, mixed, stiffened and pugged, is "slapped" or "wedged" by the thrower's assistant, who cuts the mass in two with a wire, and lifting one piece over his head, brings it down with great force on the remainder. This consolidates the body and forces out all air blisters. The cutting also reveals any impurity at the section, and the change of position at each blow thoroughly mixes the material.

The rotation of the mass tends to give a spiral direction to the formation of the vessel. The finer and more "fat" the body the greater is the torsion manifest. If a vertical line is scratched upon the piece immediately after finishing, it will be found that during drying and firing there is a torsion in the opposite direction by which the form becomes partially untwisted. For this reason an allowance is required in sticking handles on thrown ware: these are placed slanting when fixed, and attain the perpendicular during firing. (The shrinkage in height is consequently greater than the shrinkage in width.)

It is also important that the thrower should work with the sides of the fingers and not with the knuckle. The deep indentations left by the knuckles, even when smoothed, will reappear after firing, owing to the greater

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shrinkage of the finer particles of "clay slurry," which become enclosed in the furrows during formation.

The Jolley.

In the use of this machine, the clay, as it rises in position, is supported by the walls of a rotating plaster mould. This allows the formation to be carried on more rapidly. It also makes it possible to form vessels of oval shape. That part of the article which requires the greatest care and finish is made in the mould. A profile, either interior or exterior, forms the other portion.

The jolley consists of a vertical shaft similar to the potter's wheel, but having a turned iron cup fixed at the top in place of the wheel head. In this is fitted a conical plaster mould having the desired interior form. The mould fits and revolves accurately when in the cup, a series of interchangeable moulds being used.

The interior of the vessel is made with a profile, which is mounted on an arm pivoted on a standard, and can thus be lowered by hand into position within the mould (see Fig. 8). The mould is placed in position while the cup is revolving and the ball of soft clay thrown in; the profile is brought gradually down and forces the clay upward against the sides of the mould until the superfluity exudes at the top edge. This is cut off with a knife, and the form is complete.

Fig. 8.—The Jolley.
(*By permission of Messrs. York and Sons.*)

Fig. 7.—Thrower's Friction Wheel.
(*By permission of Wm. Boulton, Ltd.*)

A stop piece on the arm limits the descent of the profile and thus regulates the thickness.

The mould is now lifted out of the cup and placed in a warm room to dry. After two or three hours the clay shape has shrunk sufficiently and can be removed for finishing.

In this form of machine it is only possible to make shapes which have wide mouths and straight or conical sides.

In order to make ware having bellied form an *upright jolley* is necessary. In this machine the profile is mounted on a vertical shaft placed eccentrically with relation to the mouth of the mould. The profile descends into the mould, and after it has entered can, by a handle, be turned round, bringing the profile toward the belly of the mould. A reversed motion allows the profile to be lifted out after making (see Fig. 9).

Sometimes, however, the same object is accomplished by adding to the arm of the jolley, shown in Fig. 8, a knuckle joint, which enables the profile to fall back into the belly of the mould when required.

The form of profile should be adapted both to the material and the form of the

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vessel. Especially if the body is short, there is difficulty in making it assume the form of the mould: the clay is generally used much softer than in thrown ware. The bevel of the profile requires careful study, the object being to compress and push the clay forward and upward against the mould rather than to cut it away. The profile side of the templet is sharpened, and much depends on the bevel being at the right angle and the breadth of the templet sufficient: the narrower it is the less pressure it exerts on the clay against the mould. If the angle which the bevel makes with the plane of the mould is too large, the clay is pushed rather than cut, and it is likely to be torn away. If the bevel is too narrow, too much clay is cut away. In some forms it is necessary to adjust the bevel differently at various parts of the templet.

In white earthenware potteries, all round and oval objects required in sufficient quantities are made by the "jolley." It is also used for making crucibles, jam jars, filters, and druggists' pots.

FIG. 9.—UPRIGHT JOLLEY.
(*By permission of Wm. Boulton, Ltd.*)

THE TURNING LATHE.

The process of throwing demands that the consistency of the clay should be sufficiently soft to avoid any serious resistance to the pressure of the fingers. At the same time it must be stiff enough to support the form on its base.

Vessels with a narrow foot are, therefore, left thicker and wider outside at the base to support the weight above.

The *Turning Lathe* is used to remove the superfluous clay, to make and complete the finer mouldings, and to give a more exact form and finished surface to the piece.

With clays which are wanting in plasticity, however, recourse is had to the turning lathe to fashion the form almost entirely.

The want of cohesion in the material makes it impossible to do more than give the rough form on the wheel, which is afterwards shaped both inside and out by turning off the superfluous material on the lathe. This method is much adopted for porcelain bodies.

The ware is brought into a suitable state for turning, by stiffening it until, while still soft enough to take an impression with the nail, it will not allow the finger to leave any mark.

The object is attached to the lathe head by means of a wooden "chock" or "chum" lined with stiff clay and turned to fit the object. The object is fixed by its own plastic condition. A movable rest or prop supports the hand of the turner.

The tools required are:—

- Steel profiles for cutting the various mouldings.
- Plain chisels for cutting away the form.
- Sponges for moistening the surface.
- Calipers for measuring the size.
- Thin pieces of horn and leather for burnishing.

The process of turning does not require very great skill, and is similar to wood turning. The surface, as in the case of wood, is cut rather than scraped. The burnishing is done by steel, horn, or leather tools, the direction of the revolution being reversed.

The form of the lathe differs little from the ordinary machine, being now usually driven by power with reversing gear attached (see Fig. 10).

Heavy vessels, such as are too large to be supported on an horizontal lathe, are turned on an ordinary potter's wheel, supported vertically in a clay "chum."

Ornamental turning can be carried out by the following methods:—

Roulettes, with an engraved design which is impressed upon the semiplastic surface of the object while in motion.

Fluting or *grooving*, cut on a "dicing" lathe of the usual form; in this case, the

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vessel revolving on its axis is so arranged that it is drawn back from the fixed tool at intervals which can be made shorter or longer as desired. By this method objects made in clay, marbled or blended in different colours, may be made very ornamental.

Engine turning is also occasionally used in ornamenting vessels coated with coloured slips, the method being the same as for metal.

Banding with slips.—Coloured slips are poured carefully on the object while revolving from a vessel with a narrow spout. The slip is allowed to stiffen, and then burnished or cut as required. In some cases the slip is projected on to the surface by blowing through a tube.

FIG. 10.—THE TURNING LATHE.
(By permission of Messrs. York and Sons.)

(To be continued.)

EXPANSION CURVES FOR STEAM, GAS, OIL, AND OTHER ENGINES.

By HENRY J. JONES, A.R.C.Sc. (Lond.).

THE family of curves represented by the general equation $p v^n = c$, possesses many points of interest to the engineer. If p denotes the pressure, and v the volume of a given weight of gas, then in many practical cases we find $p v^n$ to be approximately constant; n being a mere number. Thus for the adiabatic expansion of steam at nearly all pressures we find the law $p v^n = c$, to hold. For dry steam, n averages 1·13; for steam of which the dryness fraction is 0·75, $n = 1·11$; and for steam of which the dryness fraction is 0·50, $n = 1·09$. Again, the expansion curve in an indicator diagram of a steam or gas engine is found to approximately belong to the above family of curves; and in diagrams taken from air and refrigerating machines, the above law of expansion is followed with remarkable accuracy.

It may then be of some interest to indicate a few of the properties of the above curves, and the uses to which they may be put in a study of engines working with an expansible fluid

Properties of the curve $p v^n = c$.

Suppose C C (Fig. 1) to be a portion of a curve of which the equation is of the form $p v^n = c$, the axes of co-ordinates being O V, and O P; O V being the axis of volume, and O P that of pressure. Let A, B, be any two points on the curve. Project A and B on the axes of reference as indicated, and from L and M respectively draw L T and M R inclined at 45° to the axes of co-ordinates, cutting B Q and A S (produced) in T and R respectively. Join the points T and R, so found, to the origin. Let the angles L O T $= \beta$, while the angle M O R $= \alpha$.

Since A and B are points on a curve represented by the equation $p v^n = c$, we have

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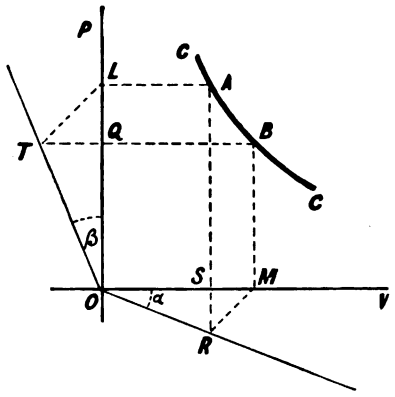

FIG. 1.

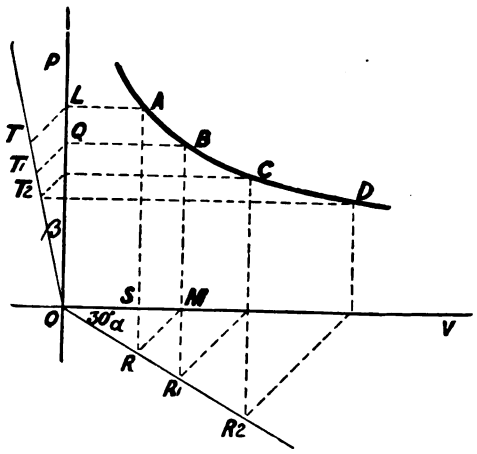

FIG. 2.

$$A\,S\,(O\,S)^n = c, \text{ and } B\,M\,(O\,M)^n = c;$$

$$\therefore (L\,Q + Q\,O)\left(\frac{O\,S}{O\,M}\right)^n (O\,M)^n = c.$$

Since the angles T L Q and Q T L are each equal to 45°, L Q = T Q.

$$\therefore (T\,Q + Q\,O)\left(\frac{1}{\frac{O\,M}{O\,S}}\right)^n (O\,M)^n = c;$$

$$\therefore O\,Q\left(1 + \frac{T\,Q}{Q\,O}\right)\left(\frac{1}{\frac{O\,S + S\,M}{O\,S}}\right)^n (O\,M)^n = c;$$

$$\therefore \left(1 + \frac{T\,Q}{Q\,O}\right)\left(\frac{1}{1 + \frac{S\,R}{O\,S}}\right)^n O\,Q.\,O\,M^n = c.$$

Now $O\,Q\,(O\,M)^n = B\,M\,(O\,M)^n = c$,

and $\frac{T\,Q}{Q\,O} = \tan\beta$, while $\frac{S\,R}{O\,S} = \tan\alpha$;

$$\therefore (1 + \tan\beta)\left(\frac{1}{1 + \tan\alpha}\right)^n = 1,$$

or $(1 + \tan\beta) = (1 + \tan\alpha)^n$.

Since the relation between tan α and tan β depends merely on n, and not on the particular points A B of the curve, it follows that consecutive points T_1, T_2, . . . on OT will correspond to consecutive points R_1, R_2 . . . on OR (see Fig. 2).

Given the Equation, to draw the Curve.

By calculation, find the co-ordinate of any point A on the curve (Fig. 2). Assume any value for α (say 30° for convenience), and from the equation $(1 + \tan\beta) = (1 + \tan\alpha)^n$ calculate the angle β. Set out the angles α and β so found, from the origin O. Project A to the axes as indicated. Draw L T making an angle of 45° with O P; and from R, where A S produced cuts $O\,R_2$, set R M at an angle of 45° with O V. Project the points T and M to intersect in B. This is a point on the curve. Now starting from B, repeat the process, and so obtain the point C; then from C obtain D, and so on. A fair curve through the points A, B, C, D, etc., is the curve required. This method is particularly useful in the case where it is desired to draw the saturated steam curve on an indicator diagram, to indicate the wetness of the steam during expansion.

If we calculate the co ordinates of two points, the points being close together for accuracy, we can avoid using the formula $(1 + \tan\beta) = (1 + \tan\alpha)^n$; and in many cases this is an advantage. Thus, suppose A and B are two points (Fig. 2), of which the co-ordinates have been obtained by calculation. Project A and B on the two axes. Draw L T at 45° to O P to meet B Q (produced) in T. Also draw M R at 45° to O V, to meet A S (produced) in S. Join T and R to the origin O. The angles α and β have thus been found graphically, and we may proceed to find other points on the curve by the previous method.

Given the curve, to find the value of the constants n and c.

Take any two points on the curve, such as A and B (Fig. 2), and by the previous method find the angles α and β. Then from the relation $(1 + \tan\beta) = (1 + \tan\alpha)^n$, calculate the value of n. Knowing n, and the value of the co-ordinates of any point such as A, we can calculate the value of c from the relation $p\,v^n = c$.

There is, however, a much more accurate method for determining the values of the constants.

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Since $p v^n = c$, we have

$$\log p + n \log v = \log c.$$

Now let $\log p = y$, while $\log v = x$, and $\log c = K$. Then we obtain

$$y + nx = K,$$

which is the equation of a straight line inclined to the axis of x at an angle θ such that $\tan \theta = -n$. By substituting $x = 0$, we find that the line cuts the axis of y in the point given by $y = K$

If, then, from our diagram we measure successive values of p and the corresponding values of v, and plot, not p and v, but $\log p$ and $\log v$, the resulting curve will be a straight line, the tangent of the angle of inclination of which to the axis of O V is $(-n)$; and the intercept of which on the axis of O P is $\log c$. Hence, from the line drawn in the manner indicated, we can directly obtain the values of n and c.

If the given curve only follows the law $p v^n = c$, approximately, the points found on plotting $\log p$ and $\log v$ will not lie accurately on a straight line. The best average line must then be drawn, and the resulting values of c and n will be the best average values for the given curve, assuming it to be of the form $p v^n = c$.

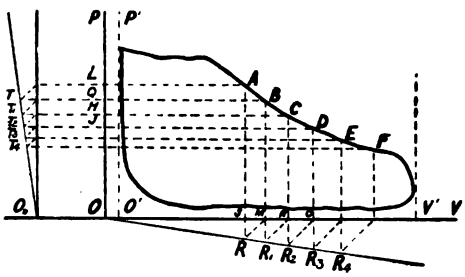

FIG. 3.

The Indicator Diagram

In the application of the first graphical method to an indicator diagram, it will be found that the points T, T_1, T_2, etc., and R, R_1, R_2, etc., do not lie absolutely on a straight line. But we may assume an average direction for them, and so obtain average values of β and α; whence we obtain, by calculation, the best average values of the constants n and c. It is recommended that the graphical method, depending upon the determination of the angles α and β, be only used in cases where it is desired to draw the curve from its given equation. The reverse process—to find the equation having given the curve—is best solved by plotting the logarithms of ordinates measured from the diagram, and proceeding as above.

It will have been noticed that the construction can only be applied in cases where the curve and the axes of co-ordinates are given. In practical cases, both axes are rarely given; usually we have only one axis—that of volume—and we have to infer the position of the other axis from a knowledge of some fact peculiar to the mechanism from which the expansion curve was obtained. Thus if we know the clearance of an engine cylinder, we can set back O' O from the extreme limit of piston-swept volume (Fig. 3), O' O being to the same scale as the piston-swept volume, and so obtain our origin, and our axis of pressure. By one of the preceding methods we may then proceed to find the equation of the expansion line of the diagram.

Graphical Determination of the Clearance.

It is interesting to note that we can find the clearance graphically from an indicator diagram; practice shows that we can obtain the clearance in gas engine cylinders correct to 4%, and in steam engine cylinders correct to 7%.

Suppose Fig. 3 to represent an indicator diagram, in which the only known axis is the zero line of pressure, O V. Select two points on the expansion part of the diagram, some distance beyond the point of cut-off. Suppose A and B to be the two points selected. Take any origin O_{11} on the axis of volume, and project A and B on the axis drawn through O_{11} perpendicular to $O_{11}V$. Set back the line inclined at 45°, as was done previously, and so obtain the point T. Join T to O_{11}. We thus have a means of finding the points T_1, T_2, T_3, etc. Project these points back to the expansion curve, and from the resulting points C, D, E, F, etc., find by projection the points S, M, N, O, etc., on the axis O V. Again, setting back the lines at 45°, we get the points R, R_1, R_2, R_3, R_4, etc. The best average line through these last points cuts the axis $O_{11}V$ in the true origin O. The distance OO' then gives the value of the clearance on the same scale as O'V' gives the volume swept out by the piston. It will be found that the clearance determined graphically from the diagram of a gas engine is always more in accordance with that found by actually filling the clearance space of the engine with an observed quantity of water, than is the case in a steam engine. This may probably be due to the condensation during expansion which occurs in a steam engine, and is absent in gas and oil engines.

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ELECTROGRAPHY: A COMPANION TO PHOTOGRAPHY.

By CHAS. R. DARLING, Assoc. R.C.Sc.Ire., Wh. Ex., A.I.C., Lecturer and Demonstrator in the Electrical Engineering Department, City and Guilds Technical College, Finsbury.

EVERY year witnesses the growth of new electro-chemical industries, and it has frequently occurred that chemical effects obtained by the aid of electricity, which at first sight appeared to have no technical application, have proved to be of great commercial value. It may therefore happen that some of the electro-chemical phenomena to be described, and embraced under the heading "electrography," may ultimately become of economic importance. An attempt has indeed been made to apply one branch of the phenomena to letter-press printing, but so far without success. Apart from the commercial side, however, the subject is of considerable interest, as demonstrating in a simple manner many curious effects of the electric current.

The term "electrography" is intended to embrace all the methods whereby, on passing a current of electricity through a suitable medium, images of the anode or kathode may be obtained either directly or by "development." The name was suggested by the analogies to photography presented by the processes; the difference consisting in the use of electricity instead of light to produce the effects.

A simple and convenient method of procuring these images or "electrographs" is by the use of the apparatus illustrated in Fig. 1. It consists of a sheet of metal A (preferably zinc or copper), on the top of which is placed an impression-pad B, consisting of a few sheets of damp blotting-paper superposed. The medium in which the images are to be obtained consists of a sheet of ordinary white paper C, damped with water or a suitable solution, according to the effect desired, as will be described later. One terminal of a battery is connected with the zinc plate, the other terminal being pressed on a metallic substance D (which may suitably consist of a coin, or small metallic block as used by printers), thereby completing the circuit through the pad and paper. Good results may be obtained by using a battery of six small accumulators, or six bichromate cells in series; whilst for quicker results wires from 100 volt mains (direct current) may be used. If arranged as shown in the figure, the coin being connected to the negative end of the battery, the direction of the current will be from the plate A (anode), to the coin D (kathode), through the pad and sheet of paper: to use the coin as anode it is only necessary to reverse the connections.

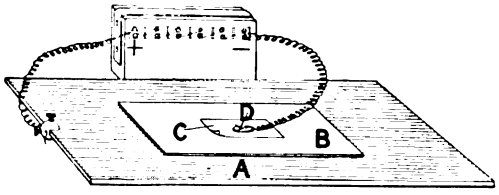

FIG. 1.
APPARATUS FOR OBTAINING ELECTROGRAPHS.

If, now, the sheet of paper C has been prepared by soaking in water and pressing out the superfluous moisture between the folds of blotting-paper—the pad having been similarly prepared—and a current of electricity be passed by pressing the negative terminal on the coin D for a few seconds, it will be found, on raising the coin, that no visible effect, other than that due to mechanical impression, is observable on the paper beneath. But if now the paper be treated in turn with silver nitrate solution and hydro-quinone, a clear black image of the coin is obtained. Any photographic developer other than hydro-quinone will produce the effect, and may be applied either before or after the treatment with silver nitrate. Nor is it necessary to "develop" the image immediately after performing the experiment; the paper may be kept for months, and will still be found capable of yielding the picture of the coin. This method of producing a picture differs from photography in so far as the paper is sensitised *after* exposure to electricity, instead of *before* exposure, as in photography. Fig. 2 is a reproduction of electrographs obtained in this manner. The lettering on the coins is, of course, reversed in the electrograph; but by employing a fusible metal mould of the coin as kathode, the ordinary appearance is presented, as shown in Fig. 3.

It cannot be said that any completely

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satisfactory explanation of the electrical latent image has yet been given. It has been suggested that the image may be due to peroxide of hydrogen: small quantities of the decomposition products of salts in the paper: occluded hydrogen: or metallic compounds dissolved from one or both electrodes. None of these suggestions is capable of explaining all the observed facts, notably the persistence of the image; and the author inclines more to the view that a permanent molecular strain is established in the medium by the current, the presence of which is manifested by the action on silver salts. It may be stated here that the images may be obtained in other media than paper, such as asbestos, which is also true of the effects to be described subsequently.

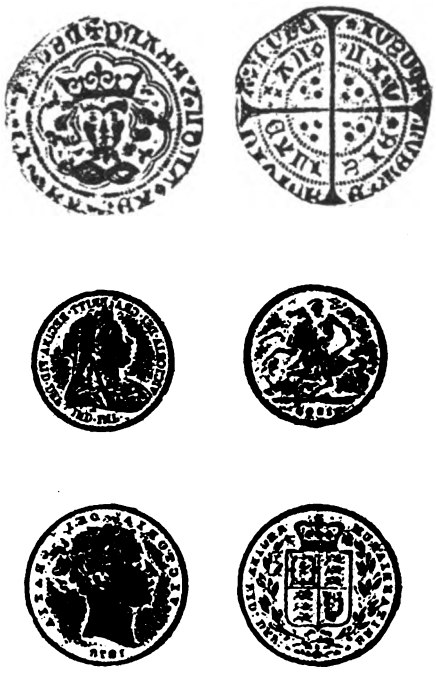

FIG. 2.—ELECTROGRAPHS OF COINS. THE LETTERING AND PATTERN ARE REVERSED, FORMING A "NEGATIVE."

A second experiment, which gives a direct picture without development, may be performed as follows: — Place a sheet of moist paper, prepared as in the previous case, on the pad, and press the *positive* terminal on a silver coin for a few seconds, the negative terminal being connected to the base-plate. Now lift the wire without removing the coin, and reverse the current, pressing the *negative* terminal on the coin for a few seconds. On raising the coin, a clear, black picture will be found on the paper beneath it. In this case the result is more easily explained: for during the first impression, when the coin is used as anode, a thin film of silver is dissolved, and enters the paper as brown hydrate, as would have been observed had the coin been lifted before reversing the wires. In the second operation this silver hydrate is decomposed, yielding a deposit of metallic silver, which has thus been obtained indirectly from the coin, and adheres to the paper. The solution of a metallic anode when a current of electricity is passed through pure paper moistened with distilled water was discovered by Cross, Bevan, and Beadle in 1896. No solution of the kathode, however, is effected, and the result here obtained is entirely distinct from the latent image previously described.

A further series of interesting results may be obtained by soaking the paper, prior to passing the current, in a solution containing a suitable electrolyte or mixture of electrolytes. As an example, the paper may be immersed for ten minutes in a 5 per cent. solution of silver nitrate; after pressing it between blotting-paper placed on the impression-pad, which is moistened with water only, the coin or other metallic article is connected to the negative terminal, and pressed on the prepared sheet for one or two seconds, when a perfect black picture will be produced, due to the liberation of metallic silver. It will be observed that the silver is only liberated at the points of contact, as the air-space between the paper and the depressed portions of the kathode acts as an insulator. Consequently, when type is used, the letters appear in the same manner as if ink had been employed, and are equally sharp and well-defined. With a view to applying this result to letter-press printing, ordinary ink being superseded by a suitable electrolyte in the paper, patents were taken out in 1898 and 1899 by W. Friese-Greene, and a syndicate was formed with a view to placing the process on a commercial basis. Unfortunately, however, the difficulties in the way of electrolytic printing proving a genuine competitor to ordinary ink-printing have so far proved insurmountable. The process is restricted by the fact that the type cannot be used as anode, as it would be dissolved away; and that the electrolyte must be cheap,

FIG. 3.
A "POSITIVE" ELECTROGRAPH, OBTAINED FROM A FUSIBLE METAL MOULD OF A HALF-CROWN.

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yield a good, permanent print, and have no deleterious action on the paper. An ordinary printing machine, with the inking mechanism removed, and suitably connected to a source of current, may be employed for electrical printing. Fig. 4 is a reproduction of electrical printing executed by the aid of the apparatus described in the present article, the paper being soaked in nitrate of silver, and afterwards "fixed" by sodium thiosulphate. In conducting an investigation with a view to finding a suitable electrolyte with which to impregnate the paper, the author obtained many curious and unexpected results, all of which may be imitated by the use of the apparatus shown in Fig. 1. Employing a coin as kathode, papers soaked in lead nitrate or acetate, mercury nitrate, or copper sulphate may suitably be used to illustrate one set of effects. On passing the current, the metal will in each case be liberated as a black deposit wherever the coin touches; but instead of remaining permanently, the deposit will be found to disappear on standing. In the case of lead salts, the image disappears entirely within an hour or two: the mercury deposit may last a few days: whilst the copper will fade in an hour or so to a yellowish-brown colour, and, after some weeks, will almost entirely disappear. A silver deposit, on the other hand, shows no signs of fading, even when kept for years. A possible explanation of the disappearance of metallic deposits other than silver, is that the acid portions of the decomposed salts remain in the paper, and gradually re-unite with the metal, reproducing the original salt. This, however, does not explain the action completely, as faded images may be restored by treatment with a silver salt and "developer." The author has thus been able completely to restore lead images after the lapse of five years, although the original disappeared in one hour. It is therefore probable that the behaviour of metallic deposits is in some way connected with the phenomena which give rise to the "latent images" previously described.

Amongst the substances which yield a permanent kathode image when contained in a film of paper or other medium, probably the best and cheapest are salts of manganese. The colour of the deposit varies according to the salt used, being dark brown with manganous sulphate, and nearly black with the nitrate. A mixture of the sulphate with nitrate of soda also yields a deposit which is almost black In each case the deposit consists of manganous hydrate, which oxidises rapidly in air, forming the higher hydrates. In attempting to produce paper containing manganese salts on the large scale for electrical printing, it was found impossible to incorporate sufficient to yield a good print without making the cost of the paper prohibitive. As the same applies to all soluble salts, it would appear that the manufacture of a cheap paper for this purpose cannot be accomplished by ordinary methods.

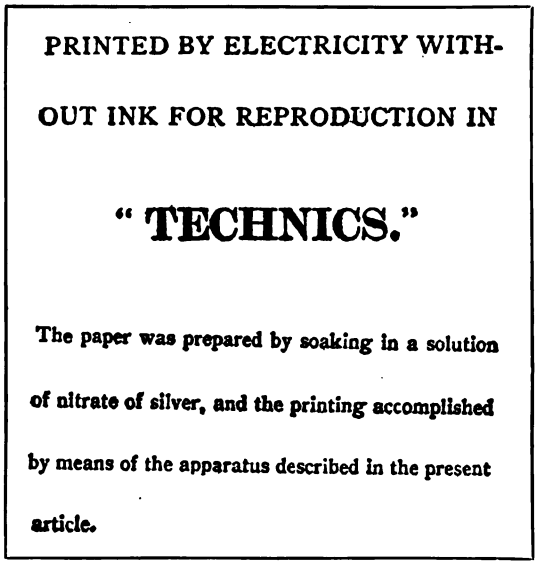
PRINTED BY ELECTRICITY WITH-
OUT INK FOR REPRODUCTION IN
"TECHNICS."
The paper was prepared by soaking in a solution
of nitrate of silver, and the printing accomplished
by means of the apparatus described in the present
article.

FIG. 4.—A SAMPLE OF PRINTING WITHOUT INK ON PAPER CONTAINING AN ELECTROLYTE.

Much remains to be discovered in connection with the whole subject of electrography. Not the least interesting of the effects are the various coloured images that may be obtained when organic substances, particularly of the class known as "developers," are contained in the paper or other medium. It is probably in one of these special branches that the commercial applications of electrography will be found, rather than in superseding ordinary ink printing. The whole subject, however, if only from the analogies presented to photography, is of much scientific interest; and has the advantage that experimental work connected with it may be carried out by anyone who has access to a source of current and a few chemicals.

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THE FIBROUS CONSTITUENTS OF PAPER.

By CLAYTON BEADLE.

Illustrated with Photo-micrographs by John Christie, F.R.M.S., and Monsieur Marcel Rostaing. Diagrams by the Author.

IN my last article the subject of linen papers was considered with more particular reference to very high-class papers made entirely of linen fibre. I chose for the purpose of this investigation the cross sections of an extremely thick linen drawing-paper, so as to give some idea of the appearance which the interstices and general arrangement of the fibres present under very high magnification; and, by way of contrast, I compared these with similar sections, both transverse, longitudinal, and vertical, of papers containing a preponderance of cotton. By way of extreme contrast, I showed a transverse section of blotting-paper (August number of TECHNICS, Fig. 6, p. 141),* which, being of necessity of a very porous texture, comprises a very large proportion of air space between the individual fibres. Such a paper, on account of its great capillarity and power of absorption, is obviously far more effective, when used for blotting ink, than paper of a closer texture: although all unsized or "waterleaf" papers can be used for blotting. Fig. 1 shows a split section of the same blotting-paper. As far as can be judged, the general distribution of the fibres is the same in blotting as in tub-sized papers, if made on similar machines. The great distinction between "blottings" and tub-sized papers, so far as their micro-structure is concerned, is that in the former the fibres lie very loosely one on the other, so that when looked at in vertical section they appear to be much further apart; they consequently possess a much larger proportion of air space, which gives them greater capacity of ink-absorption. (Contrast Fig. 6, August number, with Fig. 2, this issue.)

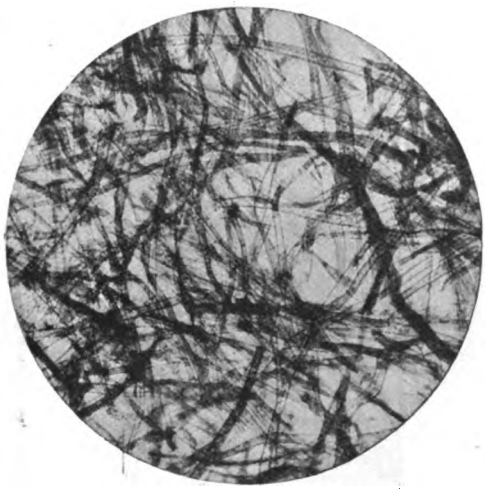

FIG. 1.—PHOTO-MICROGRAPH OF SPLIT SECTION OF BLOTTING PAPER.
(*Magnification, 60 diameters.*)

When a pull is applied to a strip of tub-sized paper by means of the paper-testing machine, it is uncertain, of course, at what point along the strip the fracture will take place. It sometimes takes place under one of the jaws: as a rule it is best to reject such fractures. It almost always starts at one or other of the edges in the exposed portion between the jaws, and proceeds to the other edge. The fracture never, however, proceeds in a straight line, but takes a more or less zig-zag course, following the lines of least resistance. The way that the "tear" proceeds is dependent upon the direction in which the strips are cut, as is evidenced in Fig. 4. A1, A2, A3 show a tear more or less zig-zag, but nearly at right angles to the edge of the strip; whereas B1, B2, B3 show a tendency to tear at an angle

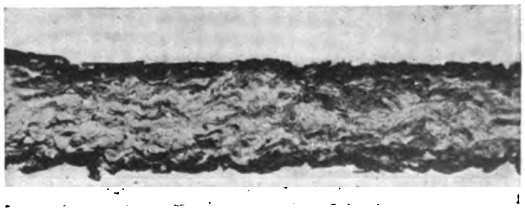

FIG. 2.—TRANSVERSE SECTION OF TUB-SIZED WRITING PAPER, SHOWING GELATINE ON SURFACE.
(*Magnification, 40 diameters.*)

* This illustration is unfortunately wrongly described. It should read, "Transverse Section of Blotting-Paper. Magnification, 40 diameters."

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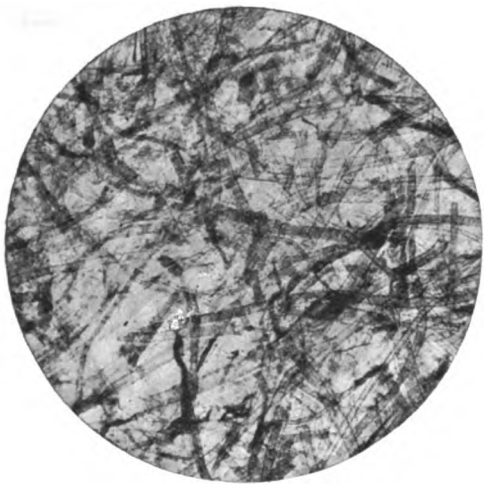

FIG. 3.—PHOTO-MICROGRAPH OF SPLIT SECTION OF TUB-SIZED PAPER, SUCH AS IS SHOWN IN TRANSVERSE SECTION IN FIG. 2.
(*Magnification*, 60 *diameters.*)

approximating to 45° to the edge of the strip. I am not prepared to offer an explanation of this difference at the present time, but there is little doubt that it has a great deal to do with the main direction of the fibres, of which we have had so many exemplifications in the photo-micrographs in previous articles. It is no doubt a matter of common observation that when we tear "news" and common wrapping papers we find it sometimes difficult to tear in a particular direction, and the tear will sometimes turn round and take a direction at right angles to the one we intended. The new course of the tear is generally parallel with one of the sides of the sheet, and in the machine direction.

Fig. 18, Part 7, page 64, shows a magnification of a mixture of cotton and linen fibres isolated from a well-known make of machine-made writing-paper; but these fibres were not easily distinguishable, on account of the severe treatment they had received in the beating engine, resulting in the mutilation of the fibres, causing the same to split up into fibrillæ and to be otherwise obliterated. In Fig. 5 we have the magnification of the fibres isolated from a paper of similar percentage composition, but differing

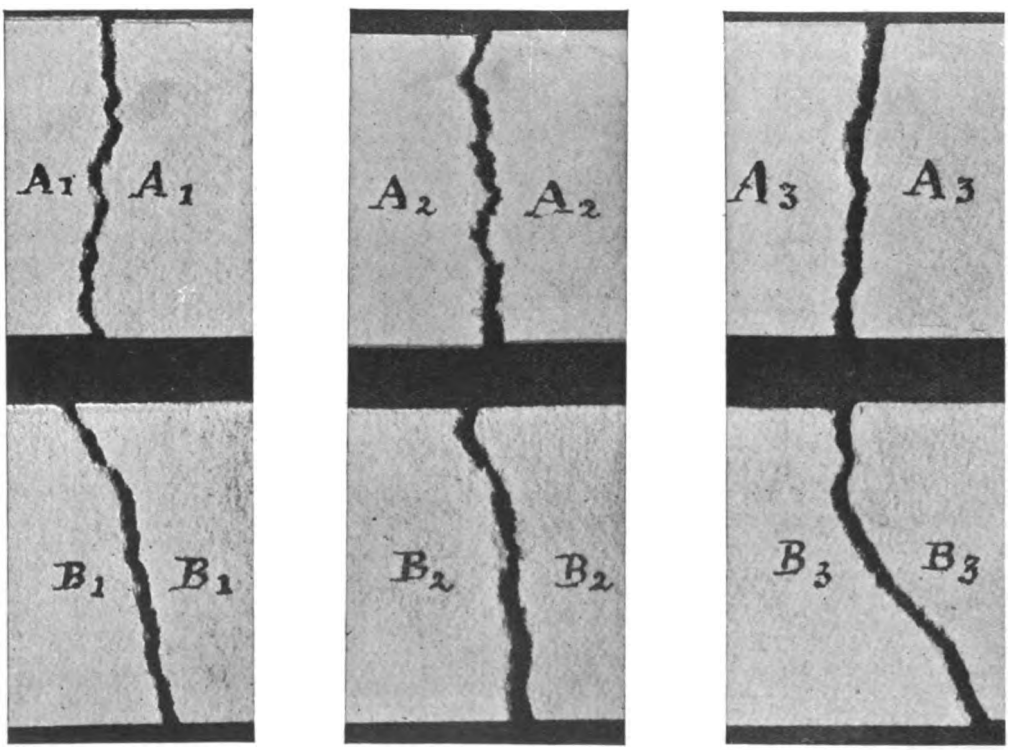

FIG. 4.—To show Characteristic Fractures of Tub-sized Paper (*c.f.* Figs. 2 and 3).
A, according to machine direction. B, according to cross direction.
(*Magnification*, 3 *diameters.*)

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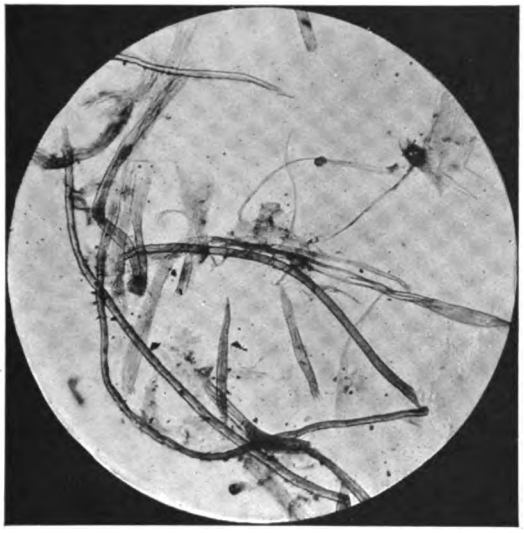

FIG. 5.—COTTON AND LINEN FIBRES OF MACHINE-MADE PAPER.
(*Magnification, 60 diameters.*)

in regard to the treatment the fibres have received in the beating engine. In this case the fibres are much less mutilated, and consequently preserve their original characteristics with greater fidelity, showing a marked contrast between the cotton and linen fibres. I do not wish it to be supposed that the former paper is inferior to the latter because of the mutilation of the fibres. This so-called mutilation, which may otherwise be described as reduction of the ultimate fibre, both in length and diameter, by subdivision into smaller particles, does not result in loss of weight or yield, but generally in loss of strength. In such papers (and there are many), where strength is of secondary, and other qualities (resulting from subdivision) are of primary importance, this mutilation is a necessity, and the desired results cannot be got without it; whilst with other papers it is a *sine quâ non* that the individual ultimate fibres shall be drawn apart without mutilation, as otherwise the desired qualities of the finished paper are not forthcoming.

The practical paper-maker is fully alive to the fact that the qualities of a paper are dependent upon the various operations performed upon it in the course of manufacture. In order that we may appreciate this, I give a diagram (Fig. 6), which is intended to convey to the lay reader the manner of operating a nand mould. We are here looking down on the operator (vatman), who stands grasping the mould by the "deckle" in the two hands. This he dips into the vat containing the beaten stuff of a thin consistency. I would point out that the watermark on mould would appear as if viewed in a looking-glass, so that when the sheet is taken from surface and turned over from right to left, the water-mark or name will read the right way round. The act of raising the mould from the vat causes a wave to pass from the long side of the deckle, immediately close to the vatman, to the other side. This wave causes a large number of fibres, more particularly those that are in the act of settling on the wire mesh, to point in the direction in which the wave travels. The vatman then gives the mould a shake from side to side, which produces waves in the opposite direction; and in some cases shakes it backwards and forwards. If the shakes were carefully adjusted we might expect to find fibres distributed equally in all directions, but on account of the wave produced when the mould is first lifted out of the vat, which predominates in its effects over any subsequent shakes, it becomes a matter of extreme difficulty to obtain uniformity even in hand-made papers. Taking hand-made papers as ordinarily made, even those of the best makes, I have failed to find regular distribution of the fibres in the finished sheet (except those very specially prepared for artists, to which

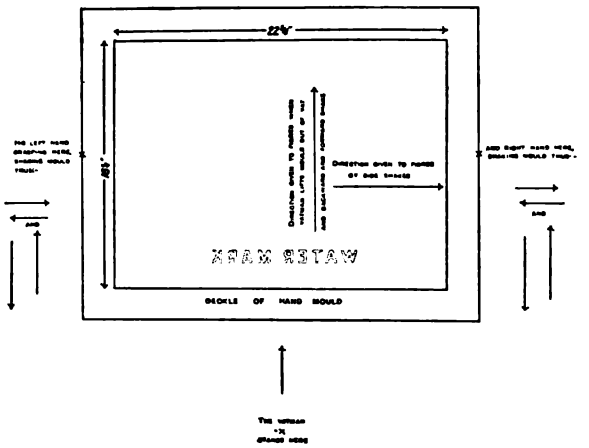

FIG. 6.—To illustrate the Handling of a Paper Mould.

The lengths of arrows show relative effects of "lifting out" and "shakes" upon direction of fibres. The "shakes" indicated by the upright arrows at side of diagram are only given occasionally.

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reference has been made in a previous article). As a consequence of the above-mentioned wave, all hand-made papers of ordinary manufacture, good, bad, and indifferent, exhibit what we may describe as a "machine direction," not only in regard to strength, but also "elongation" when tested for strength. and "least expansion when wetted." Fig. 7 is a photo-micrograph showing that the fibres tend to set themselves in the direction of the wave above referred to; it is evident, without making any measurements, that the preponderating direction of the fibres follows the path of the wave.

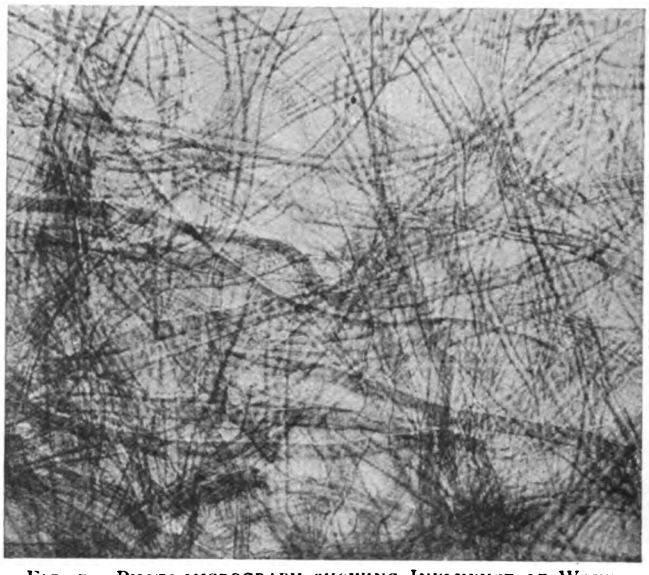

FIG. 7.—PHOTO-MICROGRAPH SHOWING INFLUENCE OF WAVE, PRODUCED BY LIFTING MOULD OUT OF VAT, ON DIRECTION OF FIBRES. (*Magnification*, 110 *diameters*.)

The effect of this upon the strength of a paper is rendered evident when a sheet of the same paper is tested for strength by the "fan" method. as is shown in Fig. 8. Notice that although the angle of greatest strength is not exactly coincident with the shorter side of the sheet or the direction of the wave, it approximates closely to it; and that the direction of least strength approximates closely to the longer side. In these respects hand-made papers show some sort of resemblance to machine-made. Now we come to a somewhat more abtruse question, but one which is of considerable commercial importance in some of the applications of papers, *viz.*, the difference of expansion exhibited in different directions of the sheet when paper is wetted with water. This I have exploited by taking discs the size of a penny at regular intervals in the sheet, and by means of the curl (to which previous reference has been made) produced by wetting on one side only, the direction of least expansion was carefully recorded. Of this I have now made several hundred determinations, both with hand-made and machine-made papers. It was determined on the individual sheet used for the fan test (Fig. 8), and its direction (72°) is indicated by an arrow on the diagram. It is interesting to note that this arrow is at right angles to the direction of least strength when pulled. This is what we should expect, because a paper tears most regularly along the direction of the fibres; in other words, it tears most readily when pulled at right angles to the direction of the fibres, since the tear takes place at right angles to the pull which occasions it. Fibres expand in diameter, but not in length. Therefore the direction of the fibres as indicated by the least strength when pulled, agrees with that as indicated by the "least expansion when wetted," and is confirmed by that of the photo-micrograph (Fig. 7), which reveals the actual direction of the fibres in question.

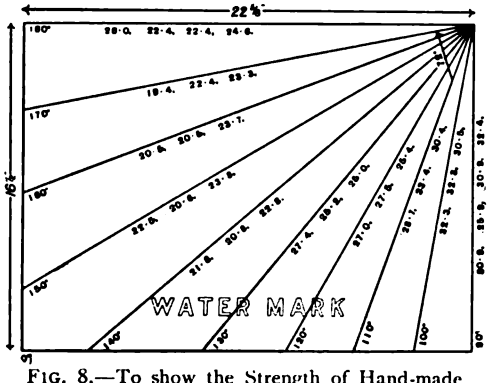

FIG. 8.—To show the Strength of Hand-made Paper at Different Angles.

Although a hand-made paper reveals the differences of strength above referred to, at different angles in any one particular sheet, it shows remarkable regularity in regard to the "least expansion when wetted,"

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when tested locally by the disc method, as diagram (Fig. 9) shows. This, as will be hereafter shown, is not the case with many of the machine-made papers. The direction of greatest and least strength, as well as the direction of least and greatest expansion when wetted, and direction of least and greatest

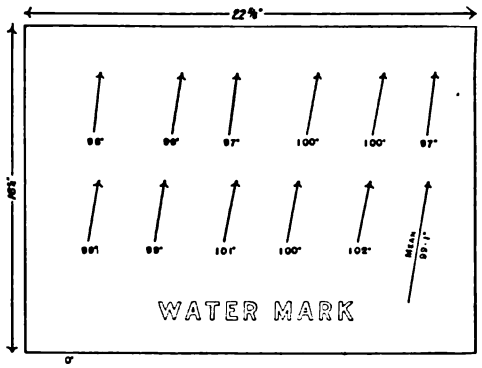

FIG. 9.—To show the Regularity, with respect to Direction of "Least Expansion when Wetted," at Different Parts of Individual Sheets of Hand-made Paper.

percentage elongation when tested for tensile strain, and such-like qualities, are determined chiefly by the treatment given to the sheet by the vatman; although the method of agitating the stuff in the vat has some influence on the finished paper. The three chief determining factors are (*a*), wave produced by lifting the mould out of the vat; (*b*), side to side shake; (*c*), backwards and forwards shake (or wave). The personal equation enters very largely into the manufacture of hand-made papers, as the relative effects of the three factors above referred to are under the control of each individual vatman; the consequence is that individual sheets vary, even when made at the same time from the same stuff, and by the same vatman. In picking up consecutive sheets of the same paper, and performing the above-mentioned tests, certain slight differences present themselves which might be traced back to the exact conditions of operating the mould.

There is a greater difficulty in ensuring regularity of thickness and weight of individual sheets of hand-made paper than there is in the case of machine-made. With a paper machine there is, or should be, a constant flow of stuff under uniform head, regular in percentage of fibre, passing on to the wet end of the machine. This flow is checked by the "slices," which act as miniature sluice-gates and prevent any local irregularities that might otherwise occur. The modern paper machine is driven at a uniform rate of speed; the consequence is, that if the machine wire and slices are exactly adjusted and everything is running as it should, a continuous web of paper is produced, uniform in thickness and weight at all parts. When the paper reaches the "cutter" it may be cut with almost mathematical precision, except in the case of a "name" paper, where a little adjustment is required to keep the name in its proper position in the sheet, at the expense, sometimes, of a slight difference in the "throw" of the cutter occasioning a slight change in the dimensions of the sheet. But even if this should occur, the sheets are made absolutely uniform in dimensions, when the paper is trimmed up under the guillotine. The great degree of uniformity can be judged by the following figures:—

Large Post, Cream Wove, Tub-Sized Extra Superfine Writing Paper, containing 50 per cent. linen and 50 per cent. new cotton, sized with 7 per cent. gelatine, sheets taken at random:

Weight of sheet. . .	10·21 grms.
" " . . .	10·19 "
" " . . .	10·27 "
Mean . . .	10·22 grms.

Variation from mean = ± 0·3 per cent., or ± ·03 grms. per sheet.

With another machine paper by the same maker I found a variation of ± 1·11 per cent.

With regard to hand-made papers, the circumstances are different. The vat has to be fortified by the addition of fresh concentrated stuff, which is made to mingle with the stuff in the vat, and is kept in agitation by means of a revolving paddle or screw. When the mould is lifted out of the vat, much of the water from the wire drains back. The difficulty of maintaining stuff of constant thickness in the vat is perhaps not the greatest one with which the vatman has to deal. The thickness and weight of sheet is determined by (*a*), the consistency of the stuff in the vat; (*b*), the depth of the "deckle"; (*c*), the way the vatman handles the mould. (*a*) and (*c*) are the means of control generally adopted. (*b*), I understand, is not, as a rule, made use of, the same depth of deckle being adhered to for different weights and any particular size.

It is not possible to manipulate the mould in such a way as to withdraw with mathematical precision the exact volume of stuff which the mould, by reason of the depth of the deckle, is capable of holding. The

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operation would be too long, and in such circumstances the mould would have to be lifted vertically upwards and kept too still for the vatman to shake the fibres together. The mould is dived under and lifted out of the stuff at an angle: by reason of the suction, it could not be raised whilst kept in a horizontal position. By a dexterous and rapid motion the mould is ducked under the stuff and raised and shaken. The amount of stuff raised on the mould will depend upon the exact manner in which the vatman performs this operation. If he is engaged to make, say 21 lbs. Large Post, he will succeed in the aggregate in producing reams of 480 sheets weighing very closely 21 lbs. There need be no material variation in bulk on comparing the reams, perhaps not more than would be noticed in weighing reams of machine-made paper; but as regards individual sheets there is considerable variation. In other words, the average result is fairly constant, whereas the individual result is somewhat variable. To secure uniformity in weight, single sheets are periodically dried and weighed, and the vatman is informed if the weight is too high or too low. The following results show the variation in weight of two makes of high-class hand-made paper, both before and after tub-sizing:—

A—Waterleaf.	A—Sized (6·8 % gelatine).
1. 14·25 grms.	5. 16·40 grms.
2. 15·90 ,,	6. 17·20 ,,
3. 16·40 ,,	7. 16·60 ,,
4. 15·40 ,,	8. 16·80 ,,
Mean 15·49 ,,	Mean 16·75 ,,
Variation from mean ±6·9 per cent., or ± 1·07 grms. per sheet.	Variation from mean ± 2·4 per cent., ± 0·45 grms. per sheet.
B—Waterleaf.	**B—Sized (8·3 % gelatine).**
1. 18·50 grms.	5. 20·30 grms.
2. 18·00 ,,	6. 17·10 ,,
3. 19·20 ,,	7. 18·30 ,,
4. 17·60 ,,	8. 17·02 ,,
Mean 18·32 ,,	Mean 18·18 ,,
Variation from mean ± 4·3 per cent., or ± 0·80 grms. per sheet.	Variation from mean ±9·0 per cent., or ± 1·64 grms. per sheet.

The above papers, both before and after sizing, were measured to see to what extent they varied in area.

	Variation between long side.	short side.		long side.	short side.
A. Waterleaf	$22\frac{3}{8}$″	$17\frac{13}{16}$″	and	$22\frac{1}{2}$″	$17\frac{7}{8}$″
A. Sized .	$22\frac{7}{16}$″	$17\frac{13}{16}$″	,,	$22\frac{1}{2}$″	18″
B. Waterleaf	$22\frac{5}{16}$″	$17\frac{3}{8}$″	,,	$22\frac{1}{2}$″	$17\frac{7}{8}$″
B. Sized .	$22\frac{1}{4}$″	$17\frac{3}{4}$″	,,	$22\frac{1}{2}$″	$17\frac{15}{16}$″

It will be seen that there is less variation in actual area than in weight. The area is determined in the first place by the size of the deckle, which is definite and constant so long as the same deckle is used. This area would have a tendency to increase, due to the "spread" of the stuff when pressure is applied at the "couching." This makes the deckle-edge shelve off and somewhat irregular, both in thickness and in outline, and so renders accurate measurement somewhat difficult. As against this we have the natural contraction of the stuff in drying, which is dependent not only on the manner in which the stuff has been beaten, but also upon the kind of fibre used. This contraction, which is a variable quantity according to the nature of the fibre and its treatment, more than outbalances the "spread" of the stuff on the deckle edge at the time of "couching." The extent of the contraction can be arrived at by measuring the sheet and comparing the same with measurement of the deckle. With rag stuff this may amount to about 4 per cent.; but the percentage contraction along the two sides at right angles to each other is not necessarily the same, even on the same sheet — in fact, is seldom so, I believe. With "wet" stuff, such as is produced from linen for the manufacture of strong papers, the contraction is greater. With "free" stuff, such as is produced from cotton for the manufacture of soft papers, the contraction may be less. Hand-made papers made from some fibres contract 10 per cent., and in one case, I know of a very "wet" fibre, which produced a sheet from a hand mould, shrinking 20 per cent., as an average of the two directions. But when the stuff is constant and the beating constant, the area of a hand-made sheet will remain fairly constant, as is shown above; and in a paper consisting half of linen and half of cotton, as above, the dimensions of the sheet are not materially affected by the tub-sizing.

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ELECTRIC LAMPS.

PART II.

By JAMES SWINBURNE, M.Inst.C.E.

AS we have seen,* the ordinary incandescent lamp is limited by the melting-point of the conductor, whether it is carbon or metal. The oxides and, perhaps, other salts of some of these metals are, however, much more refractory than the metals themselves: magnesia is a good example. But such compounds were always regarded as insulators, because they insulate very perfectly when cold. Makers of electric cooking apparatus were, to their great displeasure, familiar with the fact that their enamels electrolysed when hot; and workers at electrolytic sodium extraction knew that porcelain conducted when hot. Poincaré had measured the conductivity of hot porcelain, and the conductivity of warm and hot glass had been determined. It occurred to no one to make good use of this property until Nernst came on the scene with his lamp. He took a conductor of what pedagogues call the second class, and made a sort of filament of it. He ran it at a temperature at which it would conduct enough, and give a good efficiency, and yet would not fuse. Infusibility is not the only requisite, because the lamp must be started by initial heating; and it is not practical to heat the conductor white-hot externally whenever a lamp has to be lighted. Nernst tried a great many substances, and finally settled on zirconia as the basis of his conductor. He mixed with it a small percentage of "yttrite earth," that is to say, of a mixture of the oxides of the rare earth metals which are not precipitated by sulphate of potassium. He thus obtained a material which would begin to conduct at a comparatively low temperature, but would stand an enormous temperature before fusing. Why the addition of the yttrite earth should make it conduct at a low temperature is not known. Zirconia is an "acid" oxide, like silica, and probably the conductor is a zirconate of yttria. Like the silicates, the zirconates may form a series of compounds and mixtures ranging from pure zirconia to pure yttria. Whether there is anything in this I do not know. It is curious that the proportions of zirconia to basic oxides, in the original Welsbach patent, were almost exactly those of a normal zirconate.

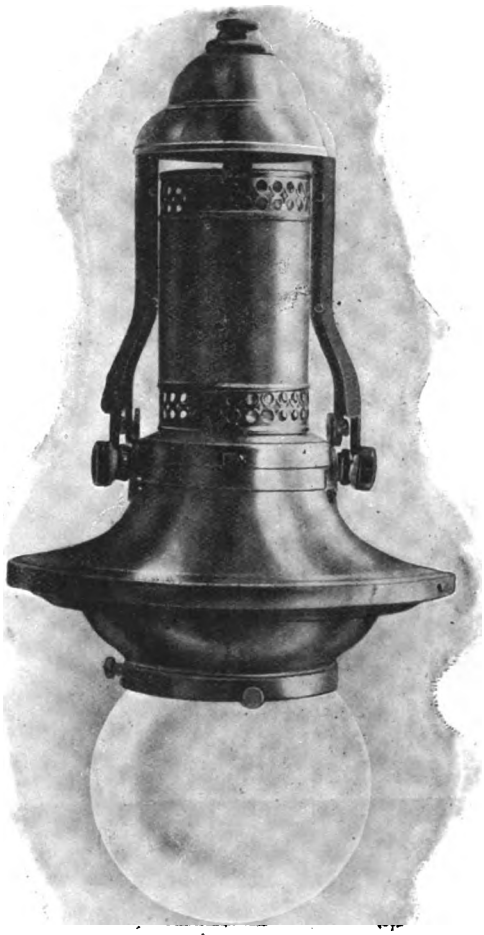

FIG. 1.—THE NERNST LAMP (Type A).

It is quite possible that the present recipe for filaments is not the best. The range of possible compounds is enormous. Though Nernst did an immense amount of research, it is impossible he can have tried everything. There is a natural tendency to begin on the rare earths, as a scientific man always prefers the waters of Abana and Pharpar to the

*Part I. of this article was published in TECHNICS, Vol. I. No. 2., February, 1904.

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common Jordan. Besides, there is a lurking idea that the rare earths have some special facilities for radiating efficiently, by selective emission or some convenient thermo-dynamic jugglement. Then there are compounds other than oxides, or rather double oxides such as the zirconates, niobates, and so on—as some people call them, "metallates." Whether there is anything better than zirconia or not, it might well be worth the time of those interested to go over the whole ground again systematically with the most modern information.

It is difficult to realise the enormous amount of work done by Nernst and his assistants. First there was the revolutionary idea of using a wire of hot oxide at all. Then, when the idea was seen to be at least practical, there were such problems as joining the glower to the leading wires. Then there was the difficulty of preliminary heating; and finally, conductors of the "second class" increase their conductivity with temperature so rapidly that a wasteful resistance has to be put in series, and the rate of increase of conductivity with temperature must be such as not to need so much series resistance—or "ballast," as the Americans with their usual felicitous language call it—as to reduce the efficiency so much as to do away with the advantage of the lamp.

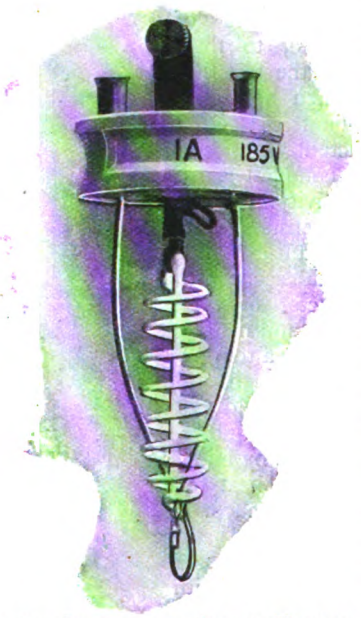

FIG. 2.—GLOWER AND SPIRAL HEATER (Type A Lamp).

Having settled on zirconia as the basis of the lamp, the next thing is to make the thin rods. Farneljehm had already made beautiful little baskets of fine threads of magnesia for use as incandescent mantles for water-gas burners, in the days before Welsbach. He squirted the wet oxide through a nozzle. He used a little acetate or nitrate also, if I remember rightly; this decomposes on heating, depositing oxide which cements the whole together, an action which is incidentally of great importance in the making of mantles. He also added gum tragacanth. This very peculiar gum makes such oxides squirt smoothly. What made anyone first think of trying gum tragacanth in this connection, or what we should do without it, I do not know. One of the most difficult matters was to purify the zirconia, and to get it in a fine enough state to squirt uniformly and homogeneously. The writer suggested calcining organic salts, such as the tartrate or oxalate; this works well, but the idea was probably tried first at Göttingen, where ingenuity is inexhaustible. The squirted rods are soft, and must be baked at a very high temperature to get them into something like their final state. A pottery furnace is of little good. Drake and Solomon did much work on baking the little rods by passing them through the arc. Finally, an electrical incandescent furnace, consisting of a tube of zirconia, was worked out, and this seems to do all that is needed.

The glowers are cut to length and mounted in fine platinum wires, by means of a paste made of the same material. In the States the mounting wires are melted at the ends into little knobs, and these are embedded in the little blobs of oxide which form the ends of the glowers. In Germany, where all the European lamps are now made, a large contact area is made between the platinum and the oxide.

It might be thought, since it took ordinary incandescent lamp-makers something like ten years to learn how to make lamps to given pressures, that the Nernst lamp would have ten similar years of tribulation. The difficulty does not come in, however, in anything like the same way. Thus, suppose a rod is of the diameter and material to be at the right temperature with one ampere, and should be a centimeter long, say, for 100 volts; if the current is increased to, say, 1·1 amperes, the pressure needed is not 110 volts, as the resistance falls. If, therefore, the rod is cut, let us say, a millimeter short, it merely takes a slightly greater current, and the ballast takes more than its share of power; the glower does not get overrun and destroyed. A slight error in the diameter, which is a greater difficulty in carbon lamps, settles itself in much the same way. As a matter of

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fact, the present glower is greatly overrun for a short time each time it is lighted, for a reason which depends on the ballast employed. The result is that the manufacture avoided one of the difficulties that loomed greatest to those who had had experience in manufacture of ordinary carbon filament lamps.

The ballast resistance gave a good deal of trouble. Of course, the obvious thing to do was to insert a simple resistance; but in order to get the necessary steadying effect without inserting enough resistance to lower the efficiency too much, it is necessary that the resistance should rise considerably with an increase of current. Fine platinum wire was wound on tiny porcelain spools; this worked well, except just when the lamp was lighted. The heat capacity of the porcelain then came into play, and the resistance did not rise quickly enough to prevent an abnormal rush when the lamp started. Recklinghausen, who did a great deal of work on the development of the Nernst lamp, used a fine platinum wire wound on a sort of fishing-line reel made so that most of the wire was free. This worked very well, as the platinum heated as quickly as the glower, so that there was no temporary overrunning on starting.

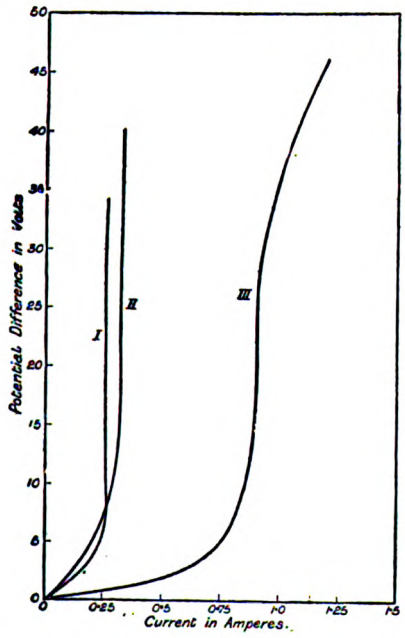

FIG. 3.—CURVES SHOWING RELATION BETWEEN VOLTAGE AND CURRENT FOR IRON WIRES.

It will be seen that, for a certain range, an infinitesimal increase of current produces a great increase of voltage.

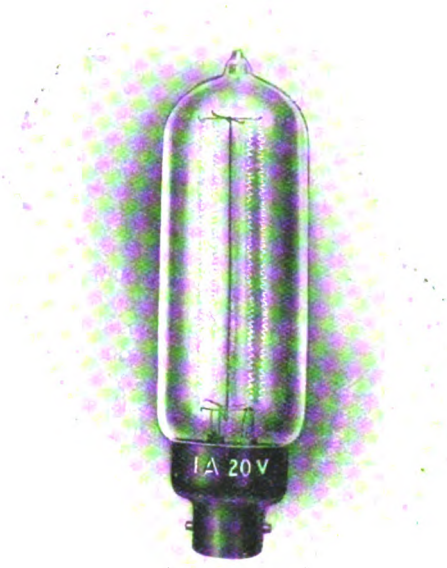

FIG. 4.—BALLASTING RESISTANCE, CONSISTING OF FOUR FINE SPIRALS OF IRON WIRE.

The present ballast, however, is a fine iron wire in a little glass bulb, containing a residual trace of hydrogen. The wire is of such a size, and the vacuum is so adjusted, that the wire gets to its critical temperature at the current required. This system is extraordinarily sensitive. The curve (Fig. 3) showing the relation of the pressure and current is almost parallel with the pressure ordinate at this point. The only drawback is that, in proportion to the pressure devoted to it, the heat capacity of the wire is higher than that of the glower, so that on starting the glower is overrun. A modern Nernst lamp gives an abnormal light for a second or two when it first lights up.

The next problem to solve was the heater. At first a platinum grid was used, which was drawn out of the way by an electromagnet when the glower began to conduct. The heater problem is exceedingly difficult. To take, say, 200 volts, and 50 watts the resistance must be 800 ohms; and 800 ohms of platinum wire must be either too expensive, or so fine as to give rise to difficulties. The wire must be held in such a way that there is little difference of pressure between the neighbouring points of support, otherwise the porcelain which is almost necessarily employed will electrolyse, as it is certain to get hot; and any silicon liberated against the platinum will attack it. The present heater (Fig. 2)

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is exceedingly ingenious. A fine rod, or generally a tube of porcelain clay, is squirted, dried, and baked. It is then wound spirally with fine platinum wire. The wire is next pasted over with "slip," to secure it from moving about. The rod is then heated in the oxyhydrogen blow-pipe, and bent round a nickel mandrel into the form of a small corkscrew. This is mounted to surround the glower. It is astonishingly strong and works very well. This resistance is cut out of circuit by a little electromagnet (Figs. 5 and 6). This little mechanism gave a great deal of trouble. It had to be made very inexpensively, and it insisted on humming on an alternating current circuit. Sometimes it does so still.

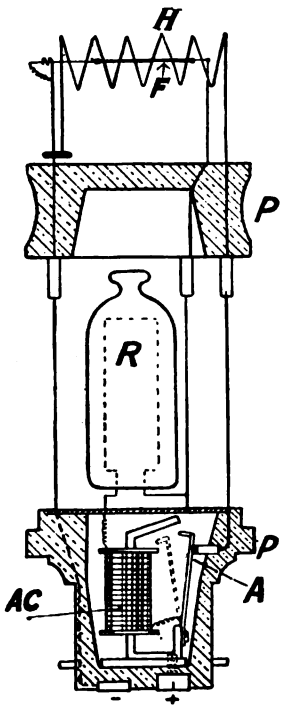

FIG. 5.—ARRANGEMENT OF MECHANISM IN NERNST LAMP (Type B).

At starting, the current enters at (+), flows through the iron tongue A to the heating coil H, and so to the negative terminal (-). When the glower becomes hot enough to conduct, current flows through the solenoid A C, the ballasting resistance R, and so through the glower F to (-). The iron tongue A is pulled aside by the action of the solenoid, and so breaks the heating circuit.

The Nernst lamp is specially useful as an intermediate between the arc and small glow lamps for shop-lighting and for the streets. It is also going ahead very rapidly in small sizes. People are slow in buying a lamp at a very much higher first cost than the carbon incandescent, though they would not have extra per point wired. People also do not study their electric light or other household accounts very carefully. The economy of the Nernst lamp is very well worth having, in spite of the extra first expense, and the difficulty of educating maidservants not to put 0·5 ampere resistances into 0·25 ampere minded a few shillings when their houses were

lamps. The chief drawback is that in most rooms there is only one lamp, and if that is a Nernst you go in for something and turn on the lamp. Nothing apparently happens, so you strike a match in an annoyed way, and get what you want, and go away. Subsequently the Nernst blossoms out alone in an empty room, and goes on until someone notices it next day or later.

The newest arrival in the way of illumination is the Hewitt lamp. This is really a vacuum tube containing mercury vapour. The mercury vapour lamp is a very old idea; but there were great difficulties in the way of making it practical. Hewitt has surmounted a good many of these. One difficulty is to start the lamp. The obvious way is to send an induction spark through first, but this is not very practical. The lamp may also be tilted, so that it short-circuits, and the arc or its analogue can then be struck. This, of course, means a resistance in series; but that is necessary anyhow, as the mercury lamp does not behave like an ordinary resistance in any case. The efficiency of the Hewitt lamp is very high—about two candles per watt. The great drawback is the colour. The light is very deficient in red, and people's complexions look horrible, like untouched photographs taken by inveterate amateurs. On the other hand, the light is very restful to the eyes for a given intensity, and draughtsmen like it much better than any other. It ought, therefore, to be adopted in drawing offices at once. It will probably be of use in printing and newspaper offices, and wherever people have to use their eyes much at night.

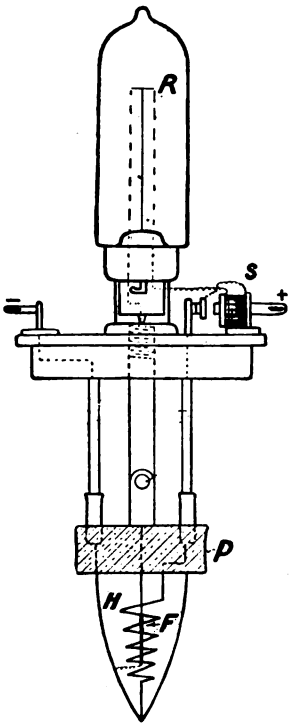

FIG. 6.—ARRANGEMENT OF NERNST LAMP (Type A).

In this case the solenoid S breaks the heating circuit when the glower F conducts.

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The light is very actinic, and instantaneous portraits can be taken. Dr. Grün recently photographed the present writer with a ten seconds exposure at $f/4$ with only one Hewitt lamp. The plate was over-exposed. Now, Dr. Grün's lens works down to some fabulous aperture ($f/2$ or so), so that with, say, ten lamps, the exposure would have been a quarter of a second; or, if for reasons of definition, or "depth of focus," the ordinary aperture of $f/4$ were used, the portrait could be taken under one second.

Various attempts have been made to improve the colour of the Hewitt light. One of the most ingenious is to let the light shine through thin silk, which is dyed with an aniline compound which fluoresces red. As Stokes showed, a body that fluoresces does so by degrading energy. It thus takes in energy corresponding to the blue end of the spectrum, and gives out red light. What is wanted, of course, is a glass or a solution which will only cut off the blue light to the extent that it gives it out as red; that is to say, it must not act like an ordinary red glass which cuts off the blue light without giving out anything in exchange.

The arc light has undergone no very striking improvement in itself for many years. The lamp of the seventies was commercial, and from 1878 to 1885 or so there was a great improvement in the mechanism, and the carbons have been made better and cheaper. One of the great drawbacks is the rapid consumption of carbons. This involves cost in material and in attendance. Recently the enclosed arc lamp has come into use. The crude idea of shutting up the arc in a globe of inert gas, so as to reduce the burning away, is old; but it has only recently been made available commercially. The realisation of the enclosed arc has brought contingent advantages in its train. The open arc carbons burn away quickly. Apart from cost of consumption, this demands frequent readjustment of the length of the arc by the mechanism. The open arc is also much shorter than the closed, so that to secure the same percentage accuracy, the adjustment must be very much more accurate. The mechanism of the open arc has thus developed into an exceedingly complicated, accurate instrument. The enclosed arc allows of a much simpler and less expensive mechanism, as the feed need not be so accurate, and is only occasional.

The open arc has the very serious drawback of needing about 55 volts. Two open arcs can be run in series on a 110 volt circuit, but on 100 volts there is not enough margin for steadying resistance, and the result is not satisfactory. The enclosed arc can be run up to 200 volts or more. This enables them to be used across ordinary town lighting circuits. The long arcs also allow the light to get out better from the crater. The enclosed arc is not perfect, though. The globe has to be small, and deposit reduces the luminous efficiency of the lamp.

Another great advance is the flame arc. In an ordinary arc practically all the light comes from the crater, and very little from the arc itself. In the flame arc the arc is fed with metallic vapours, so that it is itself luminous. The Bremer arc, for instance, uses one carbon impregnated with metallic salts.

A recent departure in arc lamps is due to Steinmetz. In this lamp the arc is itself rendered luminous by the vapour of iron or iron compounds. The negative or lower electrode is made substantially of magnetic oxide of iron, and the positive of copper. In the ordinary arc the light depends on the high temperature of the crater; but when the light comes from the arc itself, a hot crater is unnecessary, and a copper positive is employed. The spectrum of incandescent iron vapour comprises so many lines scattered throughout the spectrum that the light has no appreciable colour. The arc is long, so that the light is scarcely shaded by the electrodes, and the efficiency is very high. By mixing other materials, discovered by trial and error, with the magnetic oxide, the electrode consumption is reduced to an inch in 30 hours.

It is strange that, though the arc was the first form of the electric light, and though it has always been the most efficient, it has been less investigated than any other part of the electrical engineer's plant. Infinitely more attention has been given to wringing a small increase of efficiency out of the dynamo. One reason is that the theory of the arc is exceedingly obscure. The electron hypothesis is clearing it up to some extent; but until the advent of the electron hypothesis there was no way of tackling the theory of the arc.

We are indebted to the A. E. G. English Manufacturing Co., Ltd., for the Illustrations, Figs. 1, 2, 4, 5. 6.

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THE CHEMICAL ANALYSIS OF HIGH-SPEED STEELS AND ALLOYS.

By FRED IBBOTSON, B.Sc. (Lond.), Joint Author of "Analysis of Steel-Works Materials."

CHAPTER I.

TYPICAL ANALYSES; SAMPLING; FILTRATION.

THE suitability of a high-speed turning tool or twist drill for its work is determined primarily by the carbon, chromium, and tungsten (and perhaps molybdenum and silicon) contents, leaving out of consideration the peculiar heat treatment to which this kind of material is subjected. The amounts of sulphur and phosphorus are invariably small, and such as are incidental to the manufacture of any steel of good quality. Manganese also is present usually in small amounts only, so that the analysis, for all practical purposes, may be confined to the determination of the elements first mentioned. With respect to these, the appended table of analyses of high-speed steels, of which the commercial names, together with any opinion of their relative merits are, for obvious reasons, suppressed, may be found useful.

Mark.	Carbon.	Silicon.	Chromium.	Tungsten.
A	1·25	0·38	6·29	8·79
B	0·63	0·12	2·78	11·82
C	0·56	0·71	4·97	10·61
D	0·89	0·08	7·06	21·38
E	0·58	0·23	3·56	12·88
F	0·76	0·37	5·27	9·51
G	0·61	0·39	7·04	14·48
H	0·87	0·37	2·61	19·83
I	0·76	0·07	2·11	11·94
J	0·97	0·14	6·13	22·98
K	0·54	0·12	3·54	13·24
L	0·74	0·21	3·37	18·41
M	0·66	0·13	2·95	10·43
N	0·65	0·14	3·52	14·44

Sample N contains also nearly 0·5 per cent. of molybdenum. Sample A, made some years ago, is abnormal with respect to the amount of carbon it contains: modern steels for turning tools rarely contain more than 0·8 per cent., and the majority contain less.

Sampling.

1. *Steels.*—It is generally difficult or impossible to drill a self-hardening or high-speed steel unless it has been subjected to a suitable heat treatment. It can be effectually softened without suffering decarbonisation by putting it in a muffle furnace, surrounded on all sides by lime or bone ash rammed tightly. The muffle is brought to a full red heat, and after being maintained in this condition long enough for efficient "soaking," is allowed to cool slowly. When the temperature has fallen low enough to permit the insertion of the hand without discomfort, the steel may be withdrawn and can then be drilled with ease.

Drillings for a carbon determination should be small enough to pass through a sieve of thirty meshes per inch; but the use of a small tool, and regulation of the pressure during the drilling, yield a sample so fine as to make the sieving almost unnecessary. For chromium and tungsten determinations the size of the drillings is of no moment.

(2). *Alloys.*—A great number of the alloys used in making self-hardening steels may be drilled readily after subjecting them to the heat treatment just described for steels; but with some alloys the annealing fails to induce sufficient softness. The treatment may be dispensed with, and much time saved, by reducing the alloy to a powder in a good hardened steel mortar, though the crushing operation involves some hard manual labour, and the pestle and mortar suffer to some extent, however good they may be.

For a chromium determination, the powder should readily pass a sieve of ninety meshes per inch, whilst sievings through a sixty-mesh are sufficiently fine for carbon and tungsten determinations.

Filtration and Ignition of Precipitates.

As usually conducted, the filtration, washing, and ignition of a precipitate consume a by no means inconsiderable amount of time; and as these operations, in any one of the methods described in the following pages, involve a consumption of less than twenty minutes, the author offers no apology for advocating the use of pulp filters, the advantages of which are specifically mentioned by Jervis. (*Chemical News*, 78, 257.)

Ashless filter paper clippings are torn into small pieces and vigorously shaken in a bottle with considerably more distilled water than they can absorb. In less than five minutes a

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filtering medium of fine texture is thus obtained. A porcelain filter plate, $\frac{7}{8}$-inch in diameter, and pierced with about twenty holes each nearly $\frac{1}{16}$-inch in diameter, is placed in the throat of a *smooth* funnel of $3\frac{1}{4}$-inch diameter. Closing the stem of the funnel with the thumb of the left hand, water is then poured on in sufficient quantity to fill the stem and cover the plate, care being taken that no air is imprisoned below the latter. Sufficient pulp is then poured on to give a thickness of felting, for ordinary purposes, of no more than a $\frac{1}{4}$-inch; and having adjusted the plate in a horizontal position by means of a glass rod, the thumb is removed and the water allowed to run away, whilst a rotary motion is imparted to the funnel. By means of a spatula or pair of weight pincers, the felting is then pressed slightly and the edge tucked in, so as to prevent a rise of the pulp when liquids are poured on.

The funnel may then be arranged for suction; sufficient pressure may easily be induced by the mouth without resorting to the use of a filter pump.

A precipitate is effectively and rapidly washed by filling up the funnel twice, and after sucking the water from the stem of the funnel, which is full of liquid throughout the filtration, it only remains to transfer the precipitate (which has been rendered sufficiently dry by the suction) to the ignition dish or crucible. This operation does not at first commend itself to the manipulator. By means of a pair of weight pincers the edge of the pulp is lifted at any point, and the felting folded over about a horizontal diameter, so as to bring the under surface uppermost. This surface is then grasped by the pincers and the whole filter bodily transferred, precipitate side underneath, to the ignition dish, in which a dry piece of ashless paper has been previously placed. The precipitate, which is still moist, does not therefore make actual contact with the platinum. It now only remains to transfer the small amount of precipitate clinging to the sides of the funnel above the region previously occupied by the pulp. The funnel is grasped in the left hand, leaving the thumb free to rotate it by pressure applied at the rim, whilst a small piece of welted ashless filter paper is tightly pressed (by means of the thumb only of the right hand) against the side of the funnel. By gradually bringing the paper from throat to rim during the rotation it will be found possible in most cases, after a little practice, to remove every trace of adhering precipitate by means of a small piece of paper.

The total amount of paper to be burnt off in the event of its being found necessary to use a second piece for cleaning the funnel is considerably less than the reader might think; and no harm can be done by making absolutely certain of the thorough cleansing of the funnel by the use of still more paper.

Ignition may be commenced at once, or at any rate, after rapidly drying at the mouth of the muffle; and when completed, the ignited residue may be entirely brushed from the crucible, of which the weight is therefore not required.*

All precipitates which may be safely ignited in contact with the paper—and their number is considerably greater than a perusal of text-books on quantitative analysis would lead one to suppose—may be treated as described. The extinction of the last spark, which generally takes place in the centre of the mass, is a guarantee of complete and thorough ignition.

Precipitates of the barium sulphate type are effectually retained by using a thicker layer of pulp, but no advantage over ordinary filter papers can be claimed for pulp when handling gelatinous precipitates of the zinc sulphide type.

CHAPTER II.

The Analysis of High-speed Steels.

Determination of Carbon.

The combustion of the carbonaceous residue, left by decomposing steels containing much tungsten (and chromium) with the ordinary copper solutions, always leads to results which are decidedly low, so that a combustion of the drillings themselves is susceptible of greater accuracy. The operation, moreover, involves the use of a very simple form of combustion apparatus.

(1) *The Combustion Tube.*—All requirements are amply met by a tube made of porcelain; the length need not exceed twenty inches, but the internal diameter ought not to be less than $\frac{3}{4}$-inch. The number of combustions that can be made before the tube cracks or breaks depends upon a variety of circumstances: one important factor is the nature of the protection afforded to the heated portion of the tube. Assuming the total length of the tube to be 20 inches, the middle ten should be wrapped with asbestos

* In connection with weighing operations, the usual works practice of using a small metal scoop with counterpoise, so as to make direct weighings, merits more attention than is generally given to it in college laboratories.

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cloth, about $\frac{1}{16}$-inch thick, bound near each end and in the centre with copper wire. When the copper oxidises and crumbles away, the asbestos covering still remains *in situ*.

The tube is supported at the required height by means of two pieces of asbestos millboard, one at each end of the furnace, each pierced with a circular hole large enough for the unwrapped portion of the tube to be passed through easily. These end pieces are suitably shaped to fit the top of the furnace and effectually confine the flames, thus leaving several uncovered inches of the porcelain tube projecting on either side.

(2) *The Furnace.* — It cannot be too strongly urged that in making a direct combustion of steel drillings, a bright red heat should be attained. Given sufficient gas pressure, and using burners of the ordinary Bunsen type, this temperature may be easily reached by fixing the combustion tube at a suitable height and using a covering of arched fireclay tiles. An equal, if not superior, substitute for the tiles is furnished by thick asbestos millboard, which, after being first pierced with holes at suitable places, is thoroughly soaked in water, and then bent into the desired shape (see *Chemical News*, 77, 6). Two of these, each 5 inches long, suffice to cover the heated portion of the combustion tube; they may be allowed to dry in position.

A furnace 12 inches long, carrying the same number of burners, is quite large enough for all purposes. The front half of the heated 10 inches of the tube is occupied by a coil of copper oxide made by wrapping thin copper gauze tightly on itself, and heating the coil thus obtained in the muffle for half-an-hour in order to effect thorough oxidation. This coil constitutes the only packing required.

(3) *Accessories.* — The current of air is drawn, by means of an aspirator, through an eprouvette, or other similar contrivance, charged with soda lime. Between this and the back end of the combustion tube it is convenient to place a small bottle containing strong sulphuric acid. A stop tap or screw clip completes the absorption apparatus on this side of the furnace. The front end of the combustion tube is joined up to a capacious U-tube containing calcium chloride, which serves to retain any moisture from the drillings and the red lead with which they are mixed. The previous drying of these may therefore be dispensed with. Since the red lead effectually retains sulphur, no further absorbent is required, and the calcium chloride tube is connected with a potash bulb of the ordinary Geissler pattern (provided with a calcium chloride prolongation). The aspirator, with a capacity of at least two litres, completes the train.

Capacious porcelain boats ($4'' \times \frac{1}{2}''$), which should freely pass into the tube (many of this stated size fail to do so), serve to hold the drillings and the red lead with which they are mixed. With regard to the red lead, it seems to be impossible to procure a sample which, when ignited, does not yield small amounts of carbon dioxide. It is therefore necessary to carefully determine the amount of this; instructions are given later. Ten grams of red lead should not yield more than fifteen milligrams of carbon dioxide; samples which yield as little as ten milligrams should be carefully treasured in clean glass-stoppered bottles, and will be found to give an almost constant "blank."

(4) *The Combustion.*—The tube should be heated up cautiously in order to prevent cracking. A safe, but unpleasant, method consists in lighting each burner at the bottom through the air inlet, and allowing the gas to burn in this way for about ten minutes, after which the Bunsens under the copper oxide only may with safety be properly lighted.

After weighing the potash bulbs charged with a solution of 50 per cent. strength, four grams of the drillings, which have been passed through a 30-mesh sieve, and eight grams of the red lead, are shaken together in a glass-stoppered weighing bottle. The mixture is then spread along the interior of the porcelain boat, and after filling and coupling up the aspirator, the india-rubber plug at the rear end of the combustion tube is removed: if, on looking into the tube, the copper oxide is seen to have attained a red heat in the meantime, the boat is introduced and "pushed home" by means of a stout copper wire. The india-rubber plug is then, of course, replaced as quickly as possible. During these operations the tap of the aspirator, and that at the back end of the furnace, are kept closed.

Immediately after the introduction of the boat, bubbles are seen to pass through the potash bulbs, and the pressure is released very slightly by opening the tap of the aspirator without interfering with that at the back end of the furnace. The burners under the boat are then lighted one by one, and as the temperature rises, the amount of aspiration is gradually increased. A full red heat is attained in about five minutes, at the expiration of which time bubbling

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usually ceases. Having thus obtained a guarantee of the tightness of the apparatus, it is permissible to open the stop tap at the rear end and regulate the speed of the air current, so that about two litres pass in the course of half an hour, at the expiration of which decarbonisation of the steel should be perfectly complete.

Immediately after the burners under the boat have been lighted, it occasionally happens that there is a sudden rush of gas. It is on this account that the author advises the use of a stop-cock placed between the sulphuric acid absorption vessel and the back end of the tube; and hence also arises the necessity for the careful adjustment of the amount of "pull" by the aspirator during this critical period. In the event of a sudden rush, the fixing of the sulphuric acid bottle between the combustion tube and the soda lime eprouvette prevents a loss of carbon dioxide by back pressure.

Whilst the air current is passing, the necessary weighings for a duplicate assay should be made, so that this can be started immediately after the completion of the first. It is thus quite easy to make two combustions in less than an hour and a half.

When the first combustion is over, the top of the aspirator is closed, the potash bulbs disconnected, and finally, the boat is pulled out of the combustion tube by means of the copper wire used for its introduction. The burners under the back end of the tube just vacated by the boat are then at once turned out: the aspirator is disconnected and refilled if necessary: the second set of potash bulbs is attached; and the boat containing the mixture for a duplicate assay is introduced. The manipulation of the apparatus is then carried out exactly as already described. The open ends of the potash bulbs are kept closed whilst allowing them to stand for at least a quarter of an hour in the balance case before weighing. During this period they "pick up" at least three milligrams in weight. The bulbs should be charged with fresh potash solution when an increase in weight of half a gram has been obtained.

The ignited mass in the boat, when the latter is taken out of the tube, should be in a semi-fused condition; and most of it can be removed before solidification takes place, by means of an iron rod or the end of a small saw file, thus leaving the boat in a fit condition for a second combustion. It often happens on cooling, however, that a slight crack forms near the nose of the boat and renders it unfit for further use. A cracked boat invariably breaks when heated again, and this not only results in a sticky and disagreeable mess by forming a fusible silicate, but seriously shortens the life of the tube.

The determination of the "blank" yielded by the red lead is carried out in precisely the same manner as has just been described for a steel, ten grams of the material being used. In order to prevent the fused litharge from creeping over the sides of the boat, the latter should be furnished with an internal lining and an external covering of asbestos. This is easily accomplished by soaking thin asbestos paper in water and fitting it whilst wet to the shape of the boat. The boat is then dried and ignited in the muffle before being used.

It ought to be unnecessary to point out that, in starting a new tube, air should be aspirated for at least half an hour with the furnace at a full red heat and the weighed potash bulbs in position. These should, after allowing time for cooling, show no increase in weight.

Determination of Tungsten.

Two grams of the drillings are placed in a wide beaker of about 500 cc. capacity and covered with at least 50 cc. of concentrated hydrochloric acid. After heating nearly to the boiling-point with the cover glass in position, concentrated nitric acid is added, not more than three or four drops at a time. Each addition of the oxidant results in a vigorous frothing, which should be allowed to subside completely before a further quantity is added. By the use of such a large excess of hydrochloric acid (which, although hot, is kept as concentrated as possible), the steel may be decomposed by adding very little more nitric acid than is necessary to oxidise the iron, without causing (and this is important) any separation of tungstic oxide.

When complete decomposition has been effected, the iron should be in the ferric condition, and a black film of carbonaceous matter will have separated. The solution, which has been maintained below boiling-point, is then boiled as briskly as possible to low bulk, or until a considerable amount of tungstic oxide has separated out. It is then diluted with hot water, so that after dilution there is at least three times as much water as acid present. After boiling for a minute, the tungstic oxide is collected on a pulp filter and washed with water slightly acidulated with hydrochloric acid. After ignition in a *weighed* shallow platinum dish, a few drops of

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pure hydrofluoric acid solution are added, the excess of this carefully removed by evaporation, and the dish ignited at a full red heat for a minute. This treatment eliminates silica from the tungstic oxide.*

The residue is invariably contaminated with small amounts (5 to 10 milligrams) of ferric oxide, and often also with smaller quantities of chromic oxide. These are rapidly and completely determined by the following treatment.

The weighed residue of impure tungstic oxide is covered with two or three grams of pure dry sodium carbonate, and the dish, without mixing the contents, is placed in the hottest part of the muffle until fusion takes place. This happens in less than five minutes with a satisfactory muffle, and the dish is at once removed, shaken round, and allowed to cool. After boiling out with water, the ferric oxide is collected on a small pulp filter: its weight, after ignition, is deducted from that of the tungstic oxide. The filtrate contains the whole of the tungsten as sodium tungstate, and (if yellow) small quantities of chromium as sodium chromate. If it be considered necessary to determine the amount of the latter, the filtrate is acidulated with sulphuric acid, a slight excess (5 to 10 cc.) of decinormal ferrous ammonium sulphate solution added, and the excess of the latter titrated either with decinormal potassium bichromate or permanganate.

1 cc. $\frac{N}{10}$ ferrous solution = 0·001736 grams chromium.

1 cc. $\frac{N}{10}$ ferrous solution = 0·002536 grams chromic oxide.

After deducting the weight of chromic oxide thus obtained, the actual weight of tungstic oxide in the impure residue is found.† Tungstic oxide (WO_3) × 0·793 = tungsten.

A very large number of assays has convinced the author that the determination of the chromium in the tungstic oxide residue may, for all practical purposes, be neglected, as its amount very nearly counterbalances the two or three milligrams of tungstic oxide left in solution when the evaporation of the original solution of the steel is not conducted far beyond the point at which tungstic oxide first falls out.

Determination of Silicon.

The steel is opened out precisely as described for the tungsten determination, but the subsequent evaporation must be conducted to absolute dryness and the dry residue "baked" for at least ten minutes longer. The mass is then digested with about 20 cc. of hydrochloric acid, and when apparently all but yellow tungstic oxide has passed into solution, 60 to 80 cc. of hot water are added: after bringing to the boiling point, the silica and impure tungstic oxide are filtered off. After ignition, the loss of weight due to treatment with hydrofluoric acid represents silica.

Silica (SiO_2) × 0·4667 = silicon.

Determination of Molybdenum.

Several modern high-speed steels for turning tools contain appreciable amounts of molybdenum, the determination of which can readily be made on the filtrate from a tungsten assay. Four grams of the steel are opened out with hydrochloric and nitric acids exactly as described for the determination of tungsten, and the solution is evaporated as rapidly as possible to very low bulk, but not beyond pastiness. The mass is then boiled with a mixture of 20 cc. of concentrated hydrochloric acid and 60 cc. of water. The whole of the molybdenum remains in the filtrate when the tungstic oxide is filtered off. The latter may be ignited and weighed, but this is not advisable, since its amount, from four grams of drillings, is too cumbersome.

A solution of sodium hydrate is added to the filtrate, which is well shaken during the addition until the free hydrochloric acid is neutralised. This occurs before the formation of a permanent precipitate, or even of a pronounced darkening in colour; it is important, in order to avoid a partial precipitation of the molybdenum as a basic ferric molybdate, to stop the neutralisation with caustic alkali before the darkening in colour takes place.

The solution is then run from a separating funnel in a stream of rapid drops into an excess of hot sodium hydrate solution contained in a flask, which is vigorously agitated all the time. The amount of alkali in the solution should be at least one or two grams in excess of what is required to precipitate the iron and chromium as hydrates, and a

* In the event of the separation of tungstic oxide before complete decomposition of the drillings has been effected, the latter are protected from the attack of the acids, and the amount of impurity in the separated residue is very much larger than is desirable.

† After transferring the tungstic oxide so far as possible to the filter, it will be found that in every case a film remains on the side of the beaker which defies removal by a "policeman." A small piece of ashless filter paper, soaked with a drop or two of ammonium hydrate, readily brings it away, and the filter paper is then ignited along with the main residue.

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larger excess is beneficial rather than otherwise. By thus adding the partially neutralised mixture to the excess of caustic alkali, instead of operating in the converse manner, the molybdenum is held in solution as sodium molybdate. The iron and nearly all the chromium are precipitated as hydrates, but a small amount of the latter metal invariably passes into solution as sodium chromate. The contents of the flask are now made up to a measured amount (500 cc.), and half this amount of filtrate collected by filtration through a large dry folded paper. When a bulky precipitate of this kind is poured on a dry filter paper, traces of the precipitate very often pass through with the first runnings of the filtrate, so that it is advisable to return them to the funnel.

The 250 cc. of filtrate, representing two grams of the sample, are transferred to a capacious beaker, and hydrochloric acid added until there is an excess* of at least 5 cc. Sufficient sulphurous acid is then added to reduce the small amount of sodium chromate, and after heating the solution to boiling point, 20 cc. of lead acetate solution† (made by dissolving 10 grams of the crystals in one litre of water slightly acidulated with acetic acid) are added. A large excess (40 cc.) of ammonium acetate, made by neutralising acetic acid (B.P.) with concentrated ammonia (0·880), is finally added to the boiling solution. The ammonium acetate not only substitutes free acetic acid, in which lead molybdate is insoluble, for the free hydrochloric acid, but serves to prevent the precipitation of lead sulphate. The lead molybdate is filtered off, washed, ignited and weighed.

$PbMoO_4 \times 0{\cdot}2615 =$ molybdenum.

Determination of Chromium.

Most of the volumetric methods usually employed for the determination of chromium in ordinary steels are applicable to a high-speed tool steel. The following procedure, which is a slight modification of Galbraith's method, secures a satisfactory result in a comparatively short time.

2·4 grams of drillings are placed in a conical flask of ten-ounce capacity, and a mixture of 20cc. of concentrated sulphuric acid with 100cc. of water added. The mixture is heated, and when most of the drillings are broken up, the liquid is boiled rapidly down to low bulk, until solid ferrous sulphate begins to separate, or until the liquid bumps dangerously. The copious black residue is then treated with about 200cc. of warm water, cautiously added, and the liquid brought to the boiling point. Crystals of potassium-permanganate are then added in very small quantities at a time, until the oxidisation of the iron to ferric sulphate, and of the chromium to chromic acid, has been effected. This is apparent when a brown precipitate of manganese peroxide, which persists after boiling for a few minutes, is formed. The carbonaceous residue has now disappeared, and some tungstic oxide has separated out. A further quantity of permanganate crystals (not more than half a gram) is then added; and after washing down any small crystals adhering to the sides of the flask, the solution is boiled vigorously for three minutes. Bumping can be partially prevented by the introduction of a filter plate. The contents of the flask are then transferred to a graduated flask of 300 cc. capacity, and, after cooling, diluted to the mark, with an extra allowance of 1 cc. for the volume of the manganese peroxide precipitate. This is filtered off through two dry filter papers, and 250 cc. of the filtrate, representing two grams of steel, are collected in a graduated flask.

The clear yellow liquid thus obtained, containing the chromium as a salt of chromic acid, is then poured into an excess (50cc.) of a decinormal solution of ferrous ammonium sulphate,* and the excess of this titrated with decinormal potassium bichromate solution,† using the ferricyanide spot test indicator.

Each cc. $\frac{N}{10}$ ferrous solution used up $= 0{\cdot}001736$ grams of chromium.

* The excess of hydrochloric acid used in neutralising the alkaline filtrate for the ferric and chromic oxides, corrects a tendency to the contamination of the lead molybdate with basic compounds. The presence of the latter not only renders the results unreliable, but often causes the precipitate to fuse in the crucible. Methyl orange is useful throughout the precipitation.

† Twenty cc. of a 10 per cent. solution of lead acetate can precipitate 5 centigrams of molybdenum as lead molybdate. This amount is sufficient, operating on 2 grams of the sample, for 2·5 per cent. of the metal.

* Decinormal ferrous ammonium sulphate solution is made by dissolving 39·2 grams of the recrystallised salt in a litre of very dilute sulphuric acid (1 to 50). It must be frequently titrated with the decinormal bichromate, the strength of which remains constant.

† Decinormal potassium bichromate is made by dissolving 4·905 grams of the crystals in a litre of water.

(To be concluded.)

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART I.—TUBES OF FORCE AT REST.

By EDWIN EDSER, A.R.C.Sc.

THE importance of the electro-magnetic theory, built up by Maxwell on the experimental foundations laid by Faraday, is now fully recognised: it has formed the starting-point of many important and fruitful investigations, it led to the invention of wireless telegraphy, and some of its more recent extensions have been used in interesting speculations as to the ultimate constitution of matter. So long as this theory embodied merely the solution of Maxwell's celebrated differential equations, there was little chance of its becoming familiar to the majority of persons interested in science; but Professor J. J. Thomson, in his "Recent Researches on Electricity and Magnetism"—a work forming a fit supplement to Maxwell's classical treatise—has developed a line of reasoning which can be readily comprehended by those possessing only very moderate mathematical acquirements. The final results obtained by Professor J. J. Thomson are remarkable for their simplicity and the ease with which they may be visualised; but they were deduced by mathematical methods, which, although by no means intrinsically difficult, are yet beyond the grasp of many who are anxious to become acquainted with the subject. In the spring and summer of the present year, I delivered a short series of lectures at the Goldsmiths' Institute, with the object of presenting the salient features of the electro-magnetic theory to students whose mathematical acquirements are limited to a competent knowledge of simple equations: the interest manifested in these lectures has led me to believe that their publication, in a slightly extended form, may not be altogether unwelcome to a wider public. In acting on this belief, I wish to gratefully acknowledge my indebtedness to the works * of Professor J. J. Thomson; for any errors which may possibly be found in extensions and simplifications introduced, I must alone take the responsibility.

The fundamental phenomena of electricity and magnetism are the repulsions between similar poles and similar electric charges, and the attractions between dissimilar poles and dissimiiar charges. The laws of force are similar in the two cases: the force between two charges varies directly as the product of their magnitudes, and inversely as the square of the distance separating them: if the word "poles" is substituted for charges, we obtain the law of force between two magnetic poles. Thus the force f between two charges, q_1 and q_2, placed at a distance d apart, is given by the equation

$$f = \frac{1}{\kappa} \cdot \frac{q_1 q_2}{d^2}.$$

The symbol κ denotes a magnitude termed the *dielectric constant* of the medium in which the charges are placed; it is necessary to introduce this constant, since the force between two given charges, at a given distance apart, is different if the medium be (say) paraffin oil, from what it would be if the medium were air, or if the charges were placed in a vacuum.

The force f between two magnet poles, m_1 and m_2, separated by a distance d, may similarly be written

$$f = \frac{1}{\mu} \cdot \frac{m_1 m_2}{d^2},$$

where μ is a constant depending on the nature of the medium in which the poles are placed, and termed the *permeability* of the medium. In the electrostatic system of units, κ is assumed to be equal to unity, while in the electromagnetic system μ is assumed to be equal to unity, for empty space; the term *empty space* being used to denote a space unoccupied by any material medium, although we are obliged to suppose it to be filled by the non-material medium, the æther. Thus κ and μ, when applied to empty space, may be respectively termed the dielectric constant and the permeability of the *æther*. Now we are at perfect liberty to assume the value of either of these

* The works of Professor J. J. Thomson, to which I am most immediately indebted, are "Recent Researches," and "Conduction of Electricity through Gases" (Cambridge University Press); and "Electricity and Matter" (Archibald Constable and Co.).

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constants to be equal to unity, just as we may base our measurements on the inch or the centimeter as a unit of length; but if there is any relation between the action of one magnetic pole on another and that of one electric charge on another, we are not at liberty to assume that *both* constants are equal to unity. In the following investigation the electro-magnetic series of units will be used, so that the permeability of the æther must be taken as equal to unity; we shall find that, as a consequence, κ has a definite value which can be determined experimentally. For the present it will be convenient to confine our attention to the forces between poles or between charges surrounded only by the æther; under these conditions we have the fundamental equation

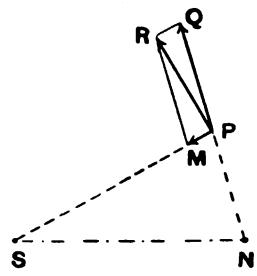

FIG. 1.

$$f = \frac{1}{\kappa} \cdot \frac{q_1 q_2}{d^2} \text{ for electric charges} \quad . \quad (1)$$

$$\text{and } f = \frac{m_1 m_2}{d^2} \text{ for magnet poles} \quad . \quad . \quad (2)$$

The positive sign is to be prefixed to a charge similar to that produced on glass when rubbed by flannel, the negative sign being prefixed to a charge of opposite kind. Similarly a positive sign is prefixed to a north-seeking, or N, pole, and a negative sign to a south-seeking, or S, pole. The value of f obtained from either (1) or (2) will indicate repulsion if its sign is positive, and attraction if its sign is negative.

Equation (2) gives us the means of defining the unit pole: this must be such that when placed at a centimeter distance from an equal pole, the force between the two is equal to one dyne. The unit charge, in the electro-magnetic series of units, cannot be obtained from (1) until the value of κ is known; when this magnitude has been determined, the unit charge can be defined as such that, when placed at a centimeter distance from another equal charge, the force between the two is equal to $1/\kappa$ dynes.

When a unit N pole is placed at a point in the neighbourhood of another pole or a combination of poles, the force acting on the unit N (or +) pole is termed the *field* at the point in question. The field at a distance d from a pole of strength m_1 is easily found, by substituting $m_2 = 1$ in. (2), when we obtain

$$\text{Field} = \frac{m_1}{d^2} \text{ dynes per unit pole.}$$

By similar reasoning, the electric field or the force acting on a unit (+) charge placed at a distance d from a charge of q_1 units, is equal to $q_1/\kappa d^2$ dynes per unit charge.

The field, whether magnetic or electric, possesses both magnitude and direction; it is therefore a vector, or directed quantity.

The field at any point P (Fig. 1), in the neighbourhood of two equal but opposite poles, can readily be determined. Let the (+) pole N have a strength of $(+m)$ units. The force acting on a unit (+) pole when placed at P will consist of two components. That due to the pole N will be equal to $\{+m/(NP)^2\}$, the positive sign showing that it is repulsive. Produce NP to Q, making $PQ = \{m/(NP)^2\}$; then PQ represents the field at P due to the pole N. The field at P due to S is equal to $\{-m/(SP)^2\}$: the negative sign shows that the force in attractive. Along the line PS measure off from P the length $PM = \{m/(SP)^2\}$; then PM represents the field at P due to the pole S. Since each component of the field is a force per unit pole, the resultant field can be found by the method employed for compounding forces. Complete the parallelogram PMRQ, and draw the diagonal PR; then PR represents the resultant field, in both magnitude and direction.

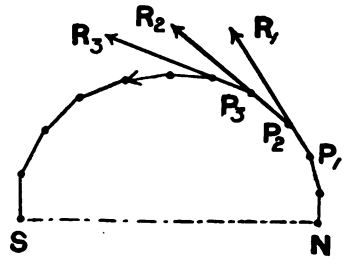

FIG. 2.

Let us now determine the field P_1R_1 at a point P_1 (Fig. 2) near the pole N. At a point P_2 near to P_1, on the line P_1R_1, once more determine the field P_2R_2. If we now determine the field at a point near to P_2 on P_2R_2, and so on, we shall ultimately obtain a series of short straight lines joined end to end, which approximate to a continuous curve as the lengths of the lines are made shorter. This curve is termed a *line of force*. From the way in which the line of force has been obtained, it is obvious that the field at any point on the curve will be tangential to the curve. If we place a small charm compass at any point of the curve, the needle will point along the tangent to the curve; for

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the N pole of the needle, by definition, tends to move along the direction of the field, while the S pole of the needle tends to move in an opposite direction. This fact draws attention to another property of a line of force: it not only has shape or form, but it also has a definite direction. If we could obtain a small isolated N pole, and were to place this at the end of NP_1S as near as possible to N (Fig. 2), then on being allowed to move freely it would travel along the line NP_1S, from N to S. *Thus a line of magnetic force always extends from a N to a S pole.*

If we suppose N (Fig. 2) to indicate a (+) and S to indicate a (−) electric charge, then the line NP_1S will represent a line of electric force. A small + charge placed at the end of this curve near N, and then given its freedom, would travel along NP_1S to the (−) charge S. *Thus, lines of electric force always extend from a (+) to a (−) charge.*

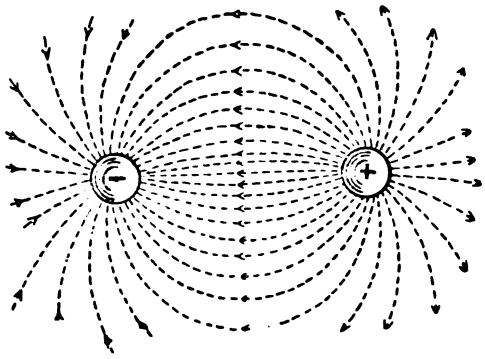

FIG. 3

It is obvious that any number of lines of force can be drawn in the space surrounding a magnet, or in that surrounding two equal but opposite charges. A number of curves are drawn in Fig. 3, which either represent the lines of force due to two equal but opposite poles, or those due to two equal but opposite charges. Each of these lines starts from the N pole (or the (+) charge) and ends at the S pole (or the (−) charge); a few of these lines, which really extend beyond the limits of the diagram, are shown broken.

Up to the present we have considered lines of force to be merely mathematical devices for indicating the direction of the field at any point; according to this view they possess no more reality than the meridians of longitude or parallels of latitude on a map. Faraday proceeded a step further, and conceived lines of force to represent actual entities. He was anxious to explain the phenomena of electricity and magnetism, and found that he could form no idea of the attractions or repulsions between two electric charges or two magnet poles, unless he could picture some sort of mechanical connection between the mutually influencing bodies. He felt it to be as impossible for a positive electric charge to pull to itself a distant negative charge without some sort of connecting mechanism, as it would be for a horse to drag a barge along a canal without a connecting rope or chain. He therefore assumed that the lines of force represent real connections between N and S poles, and between positive and negative charges; according to this view, each line in Fig. 3 tends to contract longitudinally, and so draw the two opposite poles or charges together. So far, then, Faraday considered the properties of a line of force to be somewhat similar to those of a stretched elastic filament; but if a tendency to contract were the sole property of a line of force, the peculiar shapes of the lines in Fig. 3 would be inexplicable. The straight lines joining the two poles or charges might, indeed, be merely an elastic filament; but the other lines, which follow sweeping curves bulging away from the most direct route, do not possess the forms which stretched elastic filaments would take. Faraday therefore assumed that, in addition to the property of tending to contract longitudinally, lines of force proceeding in similar directions tend to repel each other laterally. To give still greater definiteness to his idea, he assumed that the connecting links between charges are not merely mathematical lines, but rather connecting *filaments* possessing sensible sectional areas. Each of these connecting filaments tends to contract longitudinally, and also to expand or swell out laterally. The whole of the space between and surrounding the poles (or charges) is packed with these filaments; if a new filament is introduced by increasing the pole strength or the electric charges, the other filaments become more compressed. Since no two filaments can occupy the same space, some filaments are forced away from the direct route from one pole (or charge) to the other. For convenience, we may consider a number of contiguous filaments to form a bundle which may be termed a *tube of force;* two such tubes of force are shown in Fig. 4. It is with the properties of these tubes of force, in their statical and dynamical relations, that we shall be mainly concerned in the study of the Electro-Magnetic Theory. As

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it would be difficult to diagrammatically represent the tubes of force, we may consider that each line in Fig. 3 and similar diagrams represents the curved axis or centre line of a tube of force.

Having reached this stage, a little consideration will show that it is unnecessary (except for convenience of expression) to further refer to magnet poles or electric charges. The phenomena we observe and wish to explain are attractions and repulsions exerted between portions of matter in certain circumstances; since these can be explained as due to tubes of force, we may consider positive electrification to be merely the positive ends of tubes of force, while the negative ends of the same tubes constitute negative electrification. This at once explains why positive and negative charges are always simultaneously produced in equal amounts; if one end of a tube of force corresponds to a certain positive charge, the opposite end of the same tube will correspond to a numerically equal negative charge. A similar connection exists between magnetic tubes of force, and N and S magnetism. As hinted above, we may often find it convenient to speak of electric charges and magnetic poles; but it must be remembered that such terms are used merely for convenience, and do not imply the existence of anything but the ends of electric or magnetic tubes of force.

FIG. 4.

Some difficulty may perhaps be felt in imagining how the two ends of a tube of force can differ from each other. Any attempt to deduce the mechanical structure of a tube of force must be postponed until we have fully discussed its properties; but it may prove useful to remark that if the substance of which a tube of force is composed were rotating about its middle line or axis, the two ends of the tube would possess distinctive characteristics. If the direction of rotation, on looking at the (+) or N end of a tube were right-handed or clockwise, then on looking at the (−) or S end of the tube, the direction of rotation would be left-handed or counter-clockwise. If this supposition were correct, it would be easy to decide whether the end of a tube of force were (+) or (−) merely by inspection; that is, supposing that inspection were possible. The substance of which a tube of force is composed must obviously be assumed to be the æther, since tubes of force can extend across space free from matter, and containing, therefore, nothing but the æther.

FIG. 5.

It may be useful at this stage to give some idea of a mechanical arrangement which possesses the fundamental properties ascribed to a tube of force—that is, a tendency to contract longitudinally, and to expand laterally. Imagine a cylinder made from a piece of wide india-rubber tube, its two ends being closed with discs of wood or metal. Let this cylinder be entirely filled with water, and then suspended from the middle of one of the discs (Fig. 5). If the cylinder with its contained water is now set in rotation about its geometrical axis, the centrifugal force of the rotating water will produce a pressure on the flexible walls of the cylinder, which will cause them to bulge out laterally; at the same time the lower disc will be drawn upwards, even if a weight is suspended from it (Fig. 6). It would be premature to assume that tubes of force really consist of filaments of the ether rotating about their lengths; but the mechanical illustration given above may serve to give a more vivid idea of the reality of the tubes.

If an electrically charged metal sphere is placed in the middle of a large room, experiment shows that the lines of force radiate uniformly from the centre of the sphere (Fig. 7). Each tube of force has one end on the sphere, and the other end on the walls of the room; consequently a charge numerically equal to that on the sphere, but of opposite sign, is distributed over the walls of the room. Further, equal elements of area on different parts of the surface of the sphere possess equal charges, which means that the ends of tubes of force are uniformly distributed over the sphere. This result can be readily explained if we assume that the end of a tube of force can move freely over a conductor. The tubes of force will be in equilibrium under the actions of their longitudinal tensions and their lateral repulsions; since the sphere is practically equidistant from all parts of the walls of the room, there is no tendency for the tube of force to crowd into any particular path, with the result that

FIG. 6.

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the lateral repulsions of the tubes keep them symmetrically distributed (Fig. 7). If we momentarily connect the sphere to the walls of the room, the sphere is discharged; this is just what might be expected, for the two ends of each tube of force now lie on a continuous conductor, and can therefore move toward each other, as they obviously tend to do under their longitudinal tensions. An important result to be noted is, that *in a state of equilibrium, tubes of force cannot extend from one point to another of a conducting surface.* This explains why a brass rod, when held in the hand, cannot be electrified by friction; while when it is insulated, it can be as readily electrified by friction as an insulator. For reasons that will be explained as we proceed, it appears that the ultimate constituent particles of all matter are charged and cling together in virtue of the tubes of force extending from one particle to its neighbours. When we rub two bodies together, one carries off some of the negatively charged particles belonging to the other, so that tubes of force extend from the latter to the former. If the two bodies are conductors and are in electrical connection (say, by way of the body of the experimenter), then the tubes of force disappear as quickly as they are produced. On the other hand, the ends of tubes of force are unable to move over an insulator, each one being, so to speak, anchored to the point of its origin; consequently if a glass rod is rubbed with dry silk, each of these substances acquires an electric charge, the glass being positively and the silk negatively electrified.

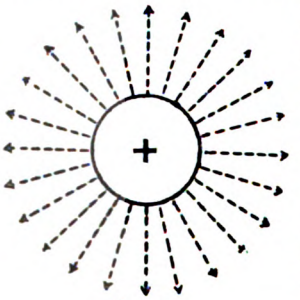

FIG. 7.

The reader who has grasped the principles explained above should find no difficulty in explaining the equal and opposite charges induced on an insulated conductor when placed near an electrified body, or the single charge induced on an earthed conductor placed near an electrified body. It should be remembered that a tube of force cannot extend through a conducting body, any more than it can extend between two points on a continuous conducting surface. Another very good exercise is to explain the great density of tubes of force near the pointed end of a conductor, and the small density of tubes of force in a hollow on a conductor.

A little consideration will show that a tube of force must enter or leave a conducting surface normally; for if it were inclined to the normal, the longitudinal tension of the tube would drag its end along the surface until the tube leaves the surface normally. Since the forces acting on a charged conductor are due to the tensions of the tubes of force, it follows that *the stresses on the surface of an electrified conductor always act normally to the surface.*

When an electrified sphere is hung in the middle of a large room, there will be no resultant force acting on it. Each tube of force is pulling normally to the surface of the sphere; and since the tubes are symmetrically distributed, the pulls on diametrically opposite elements of area are equal and opposite, so that they annul each other's effects. There will obviously, however, be a tendency to expand the sphere; if a soap bubble is electrified, it accordingly increases in size, whether the electrification be positive or negative.

When two electrified bodies are placed near each other, the distribution of tubes of force is no longer symmetrical about either body; consequently, each body is acted upon by a resultant force. When one charge is (+) and the other (−) (Fig. 3) the surfaces of the two bodies which face each other carry more tubes of force than the surfaces remote from each other; and since each tube exerts a normal pull on the surface from which it springs, it follows that the resultant force will tend to pull the bodies towards each other. The closer the bodies are brought to each other, the more the tubes of force will crowd into the space between them, and the greater will become the number of tubes ending on that surface of either body which faces the other; consequently,

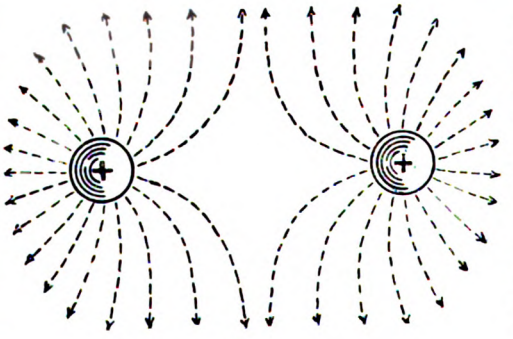

FIG. 8.

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the greater will become the force pulling the two bodies toward each other.

The distribution of tubes of force due to two similar charges is indicated in Fig. 8. Contiguous tubes proceeding in a common direction repel each other; hence, as the charged bodies are brought up toward each other, the tubes are progressively pushed out of the space between them. Consequently, the number of tubes ending on that surface of either body which faces away from the other body will increase as the bodies are brought nearer together, with the result that the bodies are pulled apart with a force which increases as the distance between them diminishes.

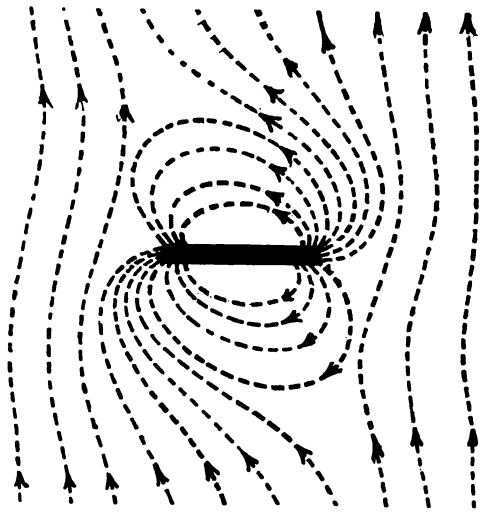

FIG. 10.

There is yet another property of stationary tubes of force which must be explained. We have already deduced the law that tubes of force stretching in a common direction repel each other; the question now arises, what is the nature of the action between neighbouring tubes stretching in *opposite* directions? The answer is, that in these circumstances an attraction is produced. This law cannot be deduced so readily as that relating to the repulsion of neighbouring tubes stretching in a common direction; but the following application of it, leading to results in agreement with experiment, serves as a sufficient justification for its adoption. Let NS (Fig. 9, *a*) be a bar of iron lying in an east-to-west direction in the earth's magnetic field. Let us suppose that the bar of iron is gradually magnetised, with the result that lines of force

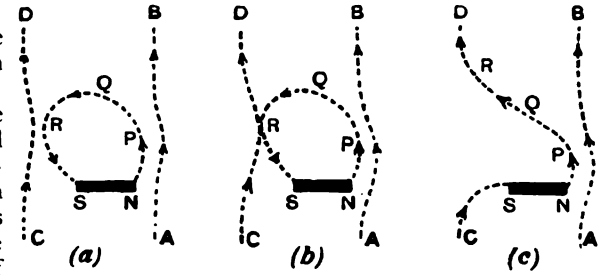

FIG. 9.

similar to NQS swell out from it. At P the line of force runs in the same direction as the line AB due to the earth's field, and therefore the two repel each other; as a result, AB is bulged outwards, and NPQ is squeezed inwards toward the magnet. At R the line of force due to the magnet runs in a direction opposite to that of the line CD, due to the earth's field; if the law stated above be true, the two lines will attract each other, and CD will bulge inwards, while QRS bulges outwards from the magnet. If we now suppose the line of force NQS to be pushed further away from the magnet by the addition of other lines, it will eventually touch the line CD at R (Fig. 9, *b*). The two lines now break at the point R, the portion NQR of the one joining on to the portion RD of the other (Fig. 9, *c*); so that NQRD now forms a continuous line, the remaining portions forming the continuous line C S. Sharp angles are smoothed out of the lines owing to their tendency to contract. It now becomes obvious why the magnet tends to set itself with the pole N pointing to the north; this is due to the pulls exerted by the lines NQD and CS. If a small magnet is placed in an east-to-west direction in the earth's field, the lines of force in its neighbourhood can be easily mapped out by the aid of a charm compass; the result is shown in Fig. 10. It is easily seen that the lines of force observed are of precisely the shape required to justify the reasoning we have adopted.

Considerable importance will subsequently be found to attach to the reasoning employed above; in addition, it is interesting as explaining how the lines of force of the earth's magnetic field link themselves on to those of a magnet.

The properties of tubes of force already deduced are independent of any theory: they embody merely the results of experiment, just as in the case of the properties of a chemical element. That a tube of force is a real entity is, of course, an hypothesis; the ultimate retention or abandonment of this

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hypothesis will depend on its agreement or disagreement with further experimental data. A speculation as to the physical constitution of a tube of force has already been mentioned; but it must be understood that such speculations are, to a certain extent, outside the electro-magnetic theory, which aims at presenting a connected account of electric and magnetic phenomena in terms of a few simple laws deduced directly from experiments. Nevertheless, it must be admitted that a theory capable of explaining electric phenomena on purely mechanical grounds is greatly to be desired; it may therefore prove interesting to see whether the vortex filament theory of tubes of force is capable of explaining, not only the repulsion between tubes proceeding in a common direction, but also the attraction between tubes proceeding in opposite directions.

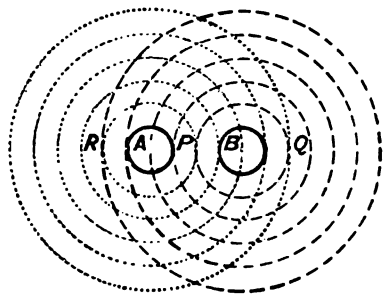

FIG. 11.

A vortex filament is a narrow tube of fluid which rotates about its centre line or axis as if it were a solid; that is, those of its particles which are farthest removed from the axis of rotation move with the greatest linear velocity, while all particles revolve with a common angular velocity. The fluid surrounding the vortex filament also acquires a circular motion; but the velocity of a particle is the less as the distance of the particle from the vortex filament is greater. Let A, B, Fig. 11, represent two vortex filaments formed in the body of a fluid. Each filament imparts a circular motion to the fluid surrounding it, and the velocity of any particle is the resultant of the velocities imparted to it by the two filaments. First, let us suppose that both A and B rotate in a common direction, say clockwise; then the velocity of the particle at Q is due to two components, both directed from the top to the bottom of the diagram; the velocity of a particle at R is due to two components directed from bottom to top of the diagram. Thus the particles at Q and R are both moving with considerable velocity. The velocity of a particle lying directly between A and B will be due to two oppositely directed components; if the vortex filaments A and B are equal in strength, a particle at P, a point midway between the two, will be stationary. Thus the velocity of the fluid in the space immediately between the vortex filaments will be less than that of the fluid on either side of the pair of filaments, and according to the well-known hydrodynamical law, "where the velocity is greatest, the pressure is least," the pressure of the fluid at P will be greater than that at Q or R, so that the filaments will tend to be forced apart, and so appear to repel each other. This obviously corresponds to the lateral repulsion of tubes of force proceeding in a common direction.

If the two vortex filaments rotate in opposite directions, it is evident that the velocity at P will be greater than that at Q or R, with the result that the pressure at P is less than that at Q or R, and the filaments tend to be forced together, and so appear to attract each other. This corresponds to the lateral attraction between tubes of force proceeding in opposite directions.

(To be continued.)

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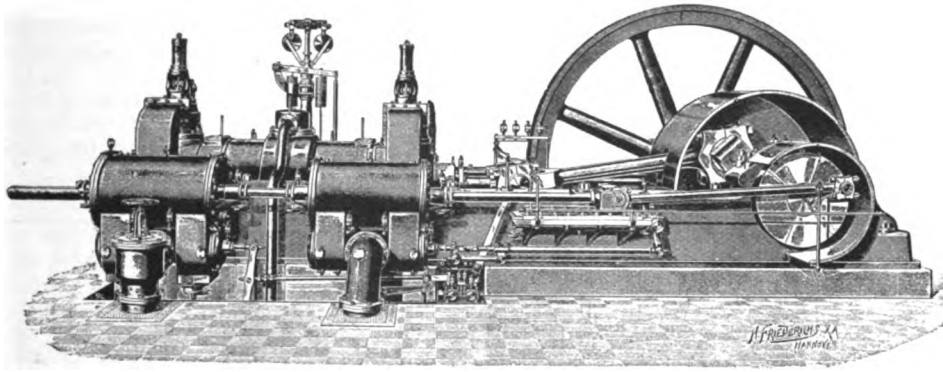
KORTING'S DOUBLE-ACTING GAS-ENGINE.



IT is well known that the thermal efficiency of gas engines is considerably higher than that of steam engines. Gas engines are, therefore, coming more and more into use, and many have recently been put down and are working satisfactorily, where not many years ago steam engines would have been installed.

Nowadays gases of low calorific value, no less than those of higher value—such as illuminating gas—can be used in gas engines without loss of efficiency or undue increase in the chief dimensions, such as cylinder diameter, etc. On the contrary, there are certain advantages in using gases containing a high percentage of carbon monoxide.

Iron and steel works especially have taken advantage of the development of the large gas engine in order to utilise their blast furnace gases, and so have coke-oven works in connection with their gases, as both types of gas are specially adapted for working internal combustion engines.

Hitherto most gas engines have been worked on the four-stroke or Beau de Rochas cycle, which, doubtless, has certain advantages where the power required is comparatively small, since the same cylinder acts as pump for the charge, and as power cylinder. With this type a practical limit for single-cylinder engines is soon reached, and large multi-cylinder engines of the tandem, twin, or four-cylinder type lead to enormous dimensions and weights. The last type especially is exceedingly complicated, and not very trustworthy. Valve boxes and admission and exhaust valves of such engines are frequently very difficult to design, and need much careful attention.

All these considerations have been taken into account in designing the engine described in this article; a series of careful experiments, extending over several years, have been made with various designs, resulting in the adoption of the type illustrated and described, and now known as Korting's double-acting two-stroke gas engine.

The Korting Cycle.

The engine is double-acting, as is a steam engine, and the working cycle is the same at both sides of the piston, *viz.*:—

1. The ignition of the charge and the development of pressure occurs near the inner dead point of the piston.
2. With the out-stroke of the piston, the power developed by the expansion of the ignited charge is transmitted to the crank.
3. At the outer dead centre the products of combustion are discharged, and admission of the new charge takes place.
4. At the in-stroke the charge is compressed.

In the Korting engine the cycle is reduced to two stages, whereas the Beau de Rochas cycle is accomplished in four stages. The discharge of the products of combustion, and the admission of the new charge, take place during the short period corresponding to the outer dead centre position of the piston. Experience shows that this can be accomplished without considerable loss of power.

As the working piston cannot suck in the charge, pumps must be used for forcing this into the cylinder; and as the products of combustion must be discharged, and the piston does not accomplish this work, the new charge must necessarily push the products of combustion out through the exhaust ports and take their place

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in the cylinder. This again necessitates that the new charge must be admitted in such a way that it ultimately fills the whole area of the cylinder, after pushing the old charge out before it; and further, that a layer of inert gas (air) is formed between the new charge and the hot products of combustion in order to avoid pre-ignition.

completely and pushes out the products of combustion, a layer of inert gas (air) being interposed between the two.

The Pumps.

In constructing the pumps (Fig. 1) the following points were taken into consideration:

In order to avoid the danger of pre-ignition

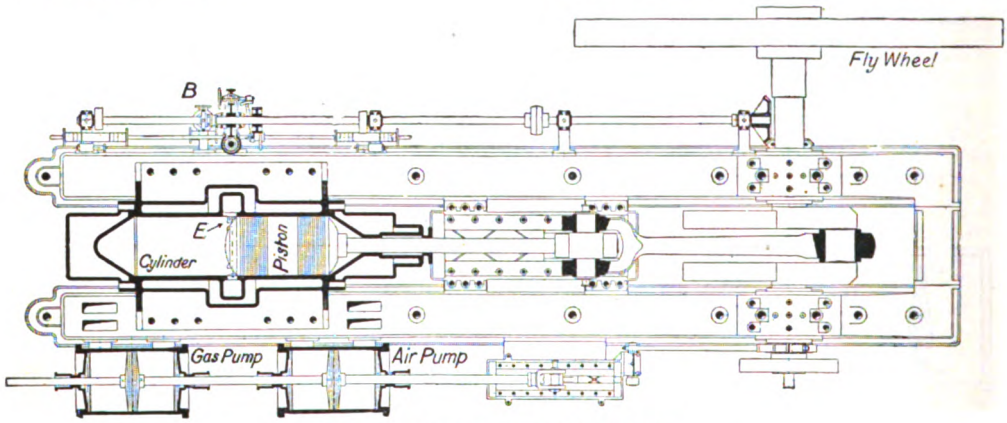

Fig. 1.—Plan of Korting Engine.
E—*Exhaust Ports.* B—*Valve for starting with compressed air.*

The requirements of the Korting cycle are accomplished by the following construction:—

The Cylinder.

The exhaust ports E (Figs. 1 and 2), are placed midway between the ends of the cylinder, and take the form of a ring of slots. The piston, which has a length equal to the stroke, less the length of the exhaust ports (about one-tenth of the stroke), closes and opens the exhaust ports alternately. The omission of exhaust valves, which are a constant source of danger to piston heads, etc., is of the utmost importance. The time which is allowed for the discharge of the products of combustion and the simultaneous admission of the new charge, is equal to that which elapses between the opening and closing of the exhaust slots, and corresponds to 90° of the crank circle. (See Indicator Diagram, Fig. 2.)

The inlet valves V, V (Fig. 2), actuated by cams, are placed at opposite ends of the cylinder. The form of the admission chambers has been constructed, after a long series of experiments, in such a way (Fig. 2) that the new charge on entering fills the area of the cylinder

the gas and air must be delivered by separate pumps, and the mixture of the two is only formed at the moment of entering the cylinder.

The pumps are constructed in such a way that pure air is first admitted to the cylinder; the composition of the explosion mixture is constant, the governor regulating the quantity of the mixture and the volume of pure air in proportion to the power required for each stroke.

The pumps do not compress the charge, but only push it into the power cylinder.

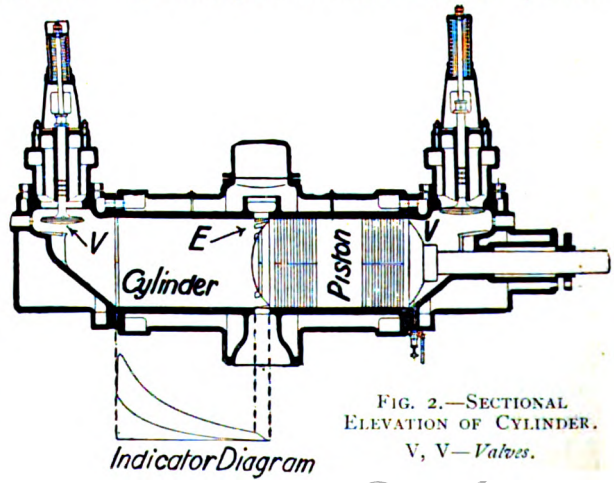

Fig. 2.—Sectional Elevation of Cylinder.
V, V—*Valves.*

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Accordingly, the pumps must nave finished their stroke when the power piston closes the exhaust ports and compression begins. This consideration fixes the crank position of the pumps in relation to the power cylinder. In order to secure a mixture of constant composition, the two pumps have a common piston-rod. They thus move together, and the composition of the mixture depends on the relative areas of the two pistons, which areas must be chosen according to the quality of the gas to be used. When the quality of gas varies to any considerable extent the pumps are constructed for the poorest gas; if the calorific value of the gas increases, it is diluted with inert gases to such an amount as to reduce it to the calorific value of the poorest gas.

The pumps push the gas and air to the admission valve through separate channels (Fig. 3), which only join at the valve itself. These channels between the gas and air pumps and the admission valve are rather long; this has to be borne in mind when considering the method of working of the engine, as gas and air are stored in the channels under a slight pressure before the inlet valve opens.

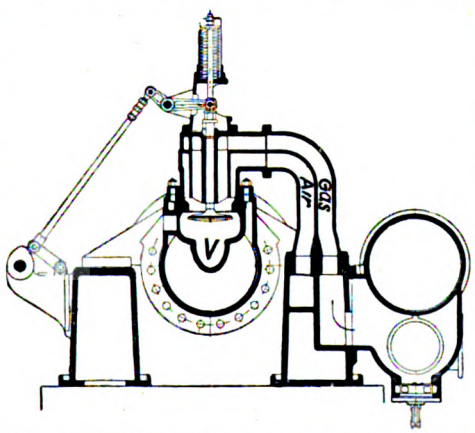

FIG. 3.—DETAILS OF VALVE OF KORTING ENGINE.

It is quite evident that, when the admission valve opens, the one of the two gases which fills the two channels in the immediate neighbourhood of the valve will enter the cylinder first; and if, for instance, means are adopted to enable the air to push back the gas from the valve, air alone will initially enter.

Bearing this in mind, the working of the pumps and the regulation of the charge will be easily understood. The pumps are so arranged that they discharge simultaneously; but as it is desired that pure air shall enter the power cylinder first, in order to form the layer of inert gas in front of the explosion mixture, it follows that the gas pump must not be allowed to deliver for a short time during which the air pump alone discharges. After this the gas pump commences to discharge the full volume of gas, corresponding to the displacement of the piston during the rest of the in-stroke, so that the mixture of gas and air is formed instantaneously.

For this purpose the gas pump valve works on a different principle from the air pump valve. The slide valve of the air pump closes and opens the suction and discharge ports in the same way as in the case of a steam engine with steam admission during the whole length of the stroke. In the gas pump, on the other hand, the closing of the suction and the opening of the pressure ports take place only after the piston has made 40 to 50 per cent. of its in-stroke; during this period the pressure ports remain closed, and the gas sucked in is forced back into the suction pipe. During the last part of the in-stroke the connection with the suction pipe is closed, and the connection to the pressure channel is opened, so that the pump discharges at its full capacity according to the area of the piston and its speed. Thus the air pump first discharges alone, while both pumps afterwards discharge at exactly the same rate, and the mixture of gas and air is therefore quite uniform in its composition.

The inlet valve V (Fig. 3) is still closed when the air pump begins to discharge, and remains closed during about half of the stroke of this pump. During this time the air collects in the channel between the pump and the valve, and becoming compressed there gradually pushes back the gas contained in the channel from the gas pump, which has not yet commenced to discharge. When the admission valve opens only air is found in its neighbourhood, and so enters the cylinder first. Not until the whole of the pure air first pumped has entered the cylinder does the gas arrive at the valve, and entering simultaneously with the rest of the air, forms the explosive mixture. The desired object is thus attained: first an isolating layer of pure air is admitted, and then a constant mixture of combustible gas.

REGULATION.

The regulation of the engine should be so arranged that the volume of the combustible charge admitted is varied according to the power required. This object can be attained in two different ways: in the first, the moment when the gas pump begins to discharge is retarded, *i.e.*, the connection between the pressure and suction chambers of the gas pump

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remains open for a longer period; and the discharge into the power cylinder commences later and is less in volume, the quality of the mixture remaining always uniform. This retardation is obtained by governing the slide valve by two different eccentrics, exactly as with the slide valve of a locomotive. This method is adopted more specially for blowing engines which have to run at variable speed. A heavy governor is necessary in such cases.

In the second arrangement, a connecting channel, opened or closed by the governor, is formed between the pressure and suction chambers of the gas pump. The discharge of the pump then remains constant, but when this channel is partly opened, some of the gas passes back from the pressure channel into the suction chamber during the suction stroke and part of the pressure stroke, and in the same proportion the gas is replaced in the pressure channel by pure air from the air pump. When the admission valve to the power cylinder opens, more pure air is admitted, followed by so much less combustible mixture, according to the volume of gas pressed back into the channel, the gas pump having first to replace this volume before the combustible mixture can be formed. The governor then regulates the volume of the gas passing back through the channel, and the volume of gas replaced by air.

Ignition.

The pure air entering first into the power cylinder does not mix with the combustible mixture on account of the peculiar arrangement of the inlet bend. The charge is not diluted: even a small charge can be ignited and burned.

With very poor gas a much earlier ignition is necessary than with richer gases. Indicator cards should be taken from time to time in order to ascertain whether the ignition takes place at the right time, and that combustion is complete. Very poor gases can be ignited without any difficulty.

The charge is ignited by magnetic inductors, and in order to secure a regular ignition of a charge which is at one time large and at another small, several igniters are provided, *viz.*, two at each side of the cylinder, one close to the inlet valve, and the other near the end of the piston "in" stroke—four in all. The inductors are operated by a small lay shaft, this being driven by gearing, from the main shaft. By altering this gear the time at which ignition takes place can be varied according to the gas used. This can be done whilst the engine is running.

When starting the engine, it is further possible to arrange for the ignition not to take place till after the dead point, which means that the engine can be started very slowly without risk of too early ignition.

Starting.

The engine is started with compressed air. For engines direct coupled to blowing cylinders a pressure of about 10 atms. or 150 lbs. is sufficient, for other engines 6–8 atms. or 90–120 lbs. This point is of the utmost importance, as the pressure of the compressed air never exceeds that of the compression with which the engine works, *viz.*, 10–12 atms. or 150–180 lbs. It is therefore absolutely impossible for the compressed air to get into the power cylinder when the piston is near its dead point, where the compression of the charge is at its highest and the ignition takes place. There is therefore no chance of the ignition either being delayed or of its failing altogether.

The compressed air is distributed by slide valves, similar to those used in steam engines, to the left and right-hand side of the cylinder. Two cylinder volumes of air are generally sufficient to start the engine. The starting arrangement itself consists of a small compressor with an air vessel, driven preferably by an electric motor.

Cooling.

In such engines, working with a high compression of the charge before its ignition, it is of the greatest importance to cool the charge so as to avoid both excessive temperatures and pre-ignition. The surface of the combustion chamber is therefore enlarged by ribs or by special pockets, through which the water circulates. The piston is carefully cooled by water entering through the hollow piston rod, and water also circulates round the glands of the valve boxes.

The temperature of the cylinder walls is, on the average, lower than in steam engines working with saturated steam of high pressure. The wear and tear in the cylinder is therefore practically nil.

In keeping the piston cooler than the cylinder itself, the expansion of the former is kept within reasonable limits, and satisfactory working of the engine is guaranteed.

The cylinder is provided with oil drain valves, acting at the same time as safety valves.

The interior of the cylinder is kept perfectly free from any incrustation. No oil-

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crusts will be found near the exhaust slots, as the burnt charge is pushed out with considerable force, alternately from the right and left side. The great advantage of such an arrangement is obvious, considering that in all engines exhausting only from one side early ignition and explosions are frequent. The low temperature of the piston also prevents the evaporation of the oil at the edges of the slots.

It is hardly necessary to point out that the weights of double-acting two-stroke gas engines are considerably lower than those of engines built on the four-stroke system

GAS LIGHTING BY FLAT FLAME BURNERS.

By THOS. HOLGATE, F.C.S., M.Inst.C.E.

ALTHOUGH the supersession of flat flames by the incandescent mantle is every year becoming more complete, yet a sufficient number of flat flame burners are sure to remain in use to make it desirable that the principle of their action should be more widely understood than it is at present. The facility with which the flat flame can be reduced to a mere tip, and the low first cost and simplicity of the burner, cause it to be used where a high illumination is not urgent, or where the light is only required at intervals. Seeing that its economy and efficiency are largely affected by a few simple yet important conditions, and that the cost of the best burner is small in comparison with that of the gas consumed, it is obvious that the general user must be financially, as well as academically, interested in the subject. The circular flame (known by the name of Argand, its inventor) and the flat flame are alike in depending for luminosity upon the glowing of the white-hot particles of carbon contained in the gaseous hydrocarbons present; whilst the "incandescent" depends upon the emission of light from a mantle of thorium and cerium, or other refractory earths, raised to the requisite high temperature by a non-luminous or Bunsen flame. The non-luminous flame may be so by virtue of the composition of the gas, but usually it is obtained by destroying the normal luminosity of coal gas by admixture, at the base of the burner, with a considerable quantity of air. It can be shown by experiment that the admixture of even a small proportion of air with gas is very destructive to the luminosity in the flat flame, and slightly less in the Argand; and further, that contact with air in the act of burning should proceed upon a definite principle. With the Argand flame the access of air to the burning gas ought to be regulated in quantity, both to the interior and exterior surfaces; and the velocity of the current should be controlled by a chimney of definite length and diameter, dependent upon the constituents and the volume of the gas employed. A flat flame is essentially similar to an Argand deprived of the air control which the chimney provides, and exposing a relatively greater surface in contact with the air; hence we may realise why it happens—all other things being equal—that with an Argand burner accurately designed a higher luminous intensity is obtained. Both types of burner exhibit two distinct areas of combustion, (*a*) the one immediately above the point of contact of the gas with air, where the luminosity is small; and (*b*) the upper, or the luminous white-hot portion of the flame. It has been shown experimentally by Professor Smithells that the two zones may be produced in separate parts of a tube; and further, that the first zone is where the hydrogen and carbon monoxide of the gas are burning to produce a temperature that transforms the hydrocarbons (contained in the gas) into others of greater carbon density, or forms carbon particles that are raised to the temperature of incandescence by coming in contact with a further supply of the oxygen of the air. If the flame be cooled by external agency, its luminosity will be diminished; and if the hydrocarbons are brought into contact with air too rapidly, the light is similarly affected. Again, if the gas issuing is low in percentage of hydrocarbons, it must emerge from a wider slit, so that it may not be excessively aerated; and the same course must be adopted if the gas is a mixture of carburetted water gas and coal gas, as the former of these needs less air than the latter. These considerations have in practice led to the following line of progress in the construction of burners :—

First.—The maintenance of the highest possible temperature in the flame, both in

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Authority.	Class of Burner.	made by W. Sugg and Co., Ltd.	Candle power of gas, burnt in standard Argand at rate of 5 c. ft. per hour.	Observations. Candle power of flame, in flatwise direction.	Observations. Gas consumed per hour, in c. ft.	Candle power of flame (flatwise) per 5 c. ft. per hour.	Duty, or percentage of the standard.	Remarks.
Paper on carburetted water gas manufacture, by the author.	Governed cone top		16·20	14·35	5·63	12·745	76·7	not designed to suit a mixture of coal gas and carburetted water gas.
	Governed table top		16·20	13·34	5·92	11·265	67·78	
	Governed cone top		18·1	16·98	4·82	17·625	97·35	designed to suit the mixed gases.
Report of Gas Referees: mixture of carburetted water gas and coal gas of the Gas Light and Coke Co.		Size No.					Shape.	Character of flame.
	Bray's regulator, union jet	4	15·8	7·4	5·10	7·3	good	steady.
	The same, with economiser No. 7	4	15·8	14·8	5·01	14·8	large	good shape, waving top.
	Bray's regulator, union jet	5	15·85	7·5	5·19	7·2	good	steady.
	Bray's regulator, union jet	6	15·85	11·7	5·71	10·2	good	steady.
	Bray's regulator, slit	7	15·0	18·0	7·02	12·8	wide	slightly forked at corners.
	Sugg's stuffed cone top	5	15·9	11·35	4·97	13·95	tall	no stiffness, almost smoking.
	Sugg's stuffed cone top	6	15·85	14·15	4·85	14·6	good	rather waving top.
	Sugg's governed cone top	5	15·45	14·1	4·98	14·15	good	waving top.
	Sugg's governed cone top	6	15·55	16·8	5·71	14·75	good	waving top.
Report of Gas Referees: 14-candle coal gas made by South Metropolitan Gas Co.	Bray's regulator, union jet	5	14·1	8·5	7·01	6·1	large	steady.
	Bray's regulator, union jet	6	14·1	10·9	7·12	7·7	good	full.
	Bray's regulator, slit	7	14·1	18·7	9·07	10·3	wide	low, slightly forked.
	Sugg's stuffed cone top	5	14·1	11·2	5·045	11·1	good	
	Sugg's governed cone top	5	14·1	12·1	5·36	11·3	good	
	Sugg's stuffed cone top	6	14·1	13·9	6·04	11·5	good	
	Sugg's governed cone top	6	14·1	15·1	6·58	11·5	good	
London County Council Official Report. Tests showing value of burners.							Duty.	Pressure.
	Sugg's governed cone top as given by the South Metropolitan Gas Company to their customers.		16·0	13·4	4·7	14·25	100·0	1·0
	Sugg's governed cone top		16·0	13·7	4·8	14·25	100·0	1·5
	Sugg's governed cone top		16·0	13·7	4·8	14·25	100·0	2·0
	Sugg's governed cone top		16·0	14·2	5·2	14·20	100·0	3·0
	Average.		16·0	13·75	4·875	14·24	100·0	1·875
	Sugg's stuffed cone top as given by the South Metropolitan Gas Company to their customers.		16·0	9·9	3·7	13·35	94·0	1·0
	Sugg's stuffed cone top		16·0	14·0	5·2	13·40	94·0	1·5
	Sugg's stuffed cone top		16·0	17·4	6·3	13·80	96·0	2·0
	Sugg's stuffed cone top		16·0	22·9	8·8	13·00	91·0	3·0
	Average.		16·0	16·05	6·0	13·39	94·0	1·875

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the lower and upper sections. This has been accomplished by discarding iron and brass tips, and using steatite or enamel, and more recently by prolonging these non-conducting tips beyond the brass casing.

Second.—The reduction of the rate of flow of the gas from the tip, so far as is consistent with the avoidance of a smoking or unsteady flame.

The devices to accomplish this are various, but they may be divided into two classes: (*a*) those that, by moving parts, automatically maintain an equilibrium of pressure or volume of the issuing gas, no matter how the inlet pressure may vary; and (*b*) those that by a permanent obstruction to the flow of gas oppose a frictional resistance that damps the variations in the rate of discharge due to variations of inlet pressure. Class (*b*) is an attempt, by simple means, and consequently at a lower price, to approximate to the more complete result of Class (*a*). Moreover, Class (*a*) may be subdivided into (*c*) those employing a governor on the pipe from the meter and controlling in a general manner the whole of the lights supplied therefrom, and (*d*) those employing a governor at the base of each burner. The last-named method is easily carried into effect; and, although it may, under certain conditions, entail a slightly greater first cost, the more perfect control over the gas consumed is an ample return on the investment. Whilst this is undoubtedly true, it must be pointed out that recent improvements have enabled an ungoverned burner to have a wider range in quantity of gas per hour than was formerly economically possible. The extent of this is shown in the fourth section of the Table on p. 374, where tests made for the L.C.C. upon burners (governed and stuffed, types of classes (*a*) and (*b*) respectively), at various pressures, gave in the former uniform results, and in the latter a large range in quantity of gas, with fair uniformity in the duty performed.

In accord with the principles just enunciated, it is found that a higher efficiency is obtained when the size of the burners is not below 4 cubic feet of gas per hour. In other words, it would be more economical to use one burner consuming 5 cubic feet per hour than two each of 2½ cubic feet.

FIG. 1.—BRAY'S REGULATOR BURNER, WITH ECONOMISER.

A striking example of the advantages of diminishing the velocity of efflux from the burner tip is furnished by the test conducted by the Gas Referees, (shown in the second section of the Table), on a No. 4 union jet burner, with and without an economiser. The economiser was a No. 7 size, and consisted of a burner head placed upon the No. 4 as a body. By this means the gas was allowed to emerge from the No. 7, or larger orifice, at a much slower rate than it did from the smaller orifice on the No. 4 size. The result shows double the light without any increase in gas consumption. The burner is made in two forms, with the head to screw or to slip on to the body, and of various sizes of head and body to suit various pressures and qualities of gas. Such a burner with a screw head is shown in Fig. 1 (Bray's burner with economiser).

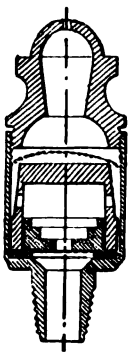

FIG. 2.—THE "VINCENT."

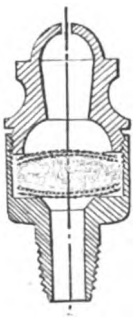

FIG. 3.—THE "CROYDON."

The governor burner "Vincent," and the ungoverned but stuffed burner "Croydon," are shown in section in Figs. 2 and 3, the former exhibiting internally a steatite or brass disc that rises with increase of pressure, and in so doing decreases the area of the side orifices that are open to the gas. The tests made by competent and independent authorities, as given in the Table (p. 374), show with what degree of accuracy this simple device does its work.

The concluding portion of the Table shows tests of burners similar to those last named, but made for use with the coal gas of 14-candle quality, supplied in the districts of the South Metropolitan Company, who distribute gratis these burners to their customers. Seeing how closely the burner and gas are interdependent, it is desirable that this practice should be extended throughout the kingdom.

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ELECTRIC WAVES.

PART III.—PRODUCTION OF ELECTRIC WAVES.

By J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London.

IN the August and September numbers of TECHNICS the outlines of the theory of electric waves have been discussed. We have in the next place to consider the method of practically producing electric waves. It has already been shown that the necessary condition is that the æther must be subjected to a very suddenly applied or reversed electric force. Up to the present time only one method has been discovered by which this can be done, and it consists in utilising the oscillatory discharge of a condenser of some kind.

If we charge a Leyden jar or condenser and discharge it through a thick copper wire having some degree of inductance produced by coiling the wire in a few turns, the discharge spark presents certain peculiarities which have earned for it the title of an oscillatory spark. If this spark is photographed upon a very rapidly moving, sensitive film or plate, the image of the spark is not merely drawn out into a long band, as would be the case if the light were perfectly continuous, but it is broken up into patches or bands (see Fig. 1), which shows that the spark is intermittent and really consists of a large number of small sparks or interrupted discharges. It can also be easily

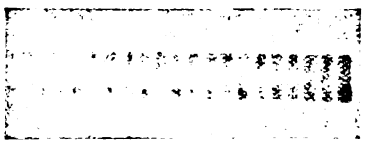

FIG. 1.—PHOTOGRAPHIC NEGATIVE, ON A MOVING PLATE, OF AN OSCILLATORY ELECTRIC SPARK.

shown that these subordinate discharges are alternately in one direction and the other.

It is a familiar fact that the discharge of an ordinary induction coil taking place through a vacuum tube consists of a series of intermittent discharges always in the same direction. This is shown by the fact that the glow light in the vacuum tube is not symmetrically distributed. Near one electrode there is a dark space, and the glow has generally different colours in the regions of the positive and negative electrodes respectively. If, however, we connect a vacuum tube to the two coatings of a Leyden jar when it is producing a discharge through an inductive circuit of low resistance, we notice that the glow light in the tube is perfectly symmetrical. Moreover, a magnet held near the tube will split the discharge into two streams. This shows that under the above conditions the discharge through the vacuum tube, and therefore the discharge of the jar, is an alternating, and not a continuous one. From an inspection of the photograph of an oscillatory spark, combined with a knowledge of the rate at which the photographic film was moving, we can calculate the frequency of such a discharge and discover that it attains a value reckoned in tens of thousands, or even millions, per second. This does not mean that there are millions of oscillations without intermittence, but that the interval of time covered by one complete electrical discharge is a small fraction of a second, which may be even less than a millionth.

As a matter of fact, each oscillatory spark may consist of ten, twenty, or thirty decadent alternating discharges, first in one direction and then in another, the interval covered by each being a very small fraction of a second.

This time of a complete discharge or single oscillation is called the periodic time or natural time-period of the condenser circuit. It is determined by the inductance of the discharge circuit and the capacity of the condenser discharging. If we denote the time-period in fractions of a second by T, and the inductance of the circuit in centimeters by L, and the capacity of the condenser in microfarads by C, then the time period T is given by the equation

$$T = \frac{\sqrt{LC}}{5 \times 10^6}.$$

If we denote the reciprocal of T by n and call this the discharge frequency, then we are

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able to calculate the frequency from the formula

$$n = \frac{5 \times 10^6}{\sqrt{LC}}$$

Thus suppose a Leyden jar having a capacity of 1/700th of a microfarad discharges through a short piece of stout copper wire having an inductance of 700 centimeters, the frequency of the electrical oscillations set up would be five millions.

Probably in this case some dozens or scores of oscillations might take place during the whole discharge, each complete oscillation lasting one five millionth of a second.

The above formula for the frequency is easily deduced from the fundamental equation expressing the facts of the oscillatory circuit. If q is the quantity of electricity in the condenser at any instant, and if v is the potential difference of its terminals and C its capacity, then $-q/C$ is the opposing electromotive force acting in the discharge circuit, of which the inductance is L and resistance R. Accordingly, by the fundamental property of such a circuit, we have,

$$L\frac{di}{dt} + Ri = -\frac{q}{C}$$

where i is the current flowing out of or into the jar at any instant. By definition the current $i = \frac{dq}{dt}$. Hence we have by substitution,

$$LC\frac{d^2q}{dt^2} + RC\frac{dq}{dt} + q = 0$$

Suppose that the resistance R of the discharge circuit including the spark gap is so small that it can be neglected. In other words, put R = 0 in the last equation, and we then have

$$\frac{d^2q}{dt^2} + \frac{q}{LC} = 0$$

This last differential equation is satisfied by assuming

$$q = Q\cos\left(\frac{}{\sqrt{LC}}\right)$$

If this is the case, then since $\cos(\theta + 2\pi) = \cos\theta$ we must have $T = 2\pi\sqrt{LC}$ as the expression for the periodic time, for the Cosine function has the same value when t is increased by T or by $2\pi\sqrt{LC}$. Hence

$$\frac{1}{T} = n = \frac{1}{2\pi\sqrt{LC}}$$

In applying this formula in practice we have to preserve homogeneity in the units. If L is measured in centimeters, that is, in electromagnetic units, then C must also be measured in the same units. It is generally convenient to reckon capacity in microfarads, and if this is the case we have to divide by 10^{15} to reduce capacity in microfarads to capacity in electromagnetic units. The final result therefore is the useful rule:—

$$\text{Frequency} = \frac{5{,}000{,}000}{\sqrt{\left(\begin{matrix}\textit{Capacity in}\\ \textit{microfarads}\end{matrix}\right) \times \left(\begin{matrix}\textit{Inductance in}\\ \textit{centimeters.}\end{matrix}\right)}}$$

To produce a continuous series of oscillations it is necessary to arrange a condenser, an inductive circuit and a spark gap in series, and to connect the terminals of the spark balls to a high tension generator such as an induction coil, an alternator or transformer.

The arrangement will be understood best by considering Fig. 2. Here C is a Leyden jar and L is an inductance coil, and S a pair

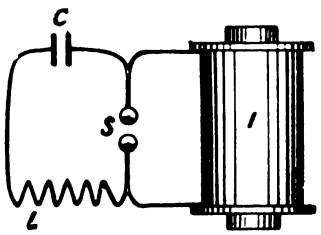

FIG. 2.—ARRANGEMENT OF OSCILLATORY CLOSED CIRCUIT.

C, Condenser; L, Inductance; S, Spark Balls; I, Induction Coil.

of spark balls, and to these last are connected the secondary terminals of an induction coil I. When the spark balls are adjusted near to each other and the coil set in action a continuous series of noisy sparks pass across between the balls. These sparks are oscillatory. When a transformer is employed, special means have to be adopted to quench the alternating current arc which then tends to form. The student should clearly realise the physical operations taking place. As the induction coil or transformer gradually builds up an electromotive force it charges the condenser and creates an increasing potential difference between the spark balls. If the balls are placed at the right distance apart, then at a certain value of this potential difference the insulation of the air between them breaks down (corresponding to a certain electric force), and the air passes suddenly into a conductive condition. The condenser

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then discharges, but this discharge is just like the release of a spring. Owing to the electric inertia of the circuit the discharge over-shoots the mark, and it dies away by a gradually decrescent but alternating series of discharges or oscillations. These oscillations are very brief electric currents, but during the time they are flowing, their maximum values are sometimes very considerable. A circuit consisting of a condenser, an inductance and a short spark gap, can in this manner become the seat of very powerful electric oscillations, but these do not throw off very powerful electric waves. Such a closed circuit is very non-radiative. To enable it to create electric waves it must be associated with a radiator or antenna, or else be given such a form that it radiates itself. We may make the closed oscillatory circuit radiate by one of two methods. The radiating antenna may be associated with it directly or inductively. The first method is shown in Fig. 3, where a closed non-radiating circuit has a radiator attached to one point of it, another point being earthed.

To secure effective or powerful radiation, the antenna must have its length adjusted in accordance with a certain law. When a wave

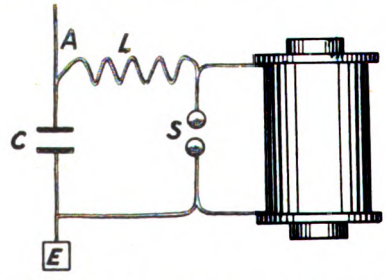

FIG. 3.—ARRANGEMENT OF RADIATIVE OSCILLATORY CIRCUIT.
A, Ærial or Antenna; C, Condenser; L, Inductance; S, Spark Balls; I, Induction Coil; E, Earth Plate.

motion is produced in the æther it travels through it with a certain velocity V equal to thirty thousand million centimeters, or nearly 1,000 million feet, per second. If the wave motion has a wave length λ, and a frequency n, then n, λ, and V are connected by the equation

$$V = n\lambda.$$

It can be shown that to secure effective radiation we must make the length of the antenna or aerial wire such that four times its length in feet is equal to the quotient of 10^9 by the frequency n of the closed oscillating circuit. This frequency is fixed by the capacity C and inductance L possessed by the circuit, and the rule for calculating n from C and L has already been given. Suppose then that we have a condenser or Leyden jar of capacity C microfarads, and we connect it to an inductance of L centimeters, and to a spark gap, so as to make an oscillatory circuit. We desire to make this arrangement radiate electric waves. We therefore attach an aerial wire or antenna of height h feet. The practical question arises what relation should exist between C, L, and h to get the best result. The answer, on the above explained principles, is given by the equation :—

$$h = 50\sqrt{C\,L}.$$

Hence, if the condenser is a Leyden jar having a capacity of $\frac{1}{700}$ microfarad, and the coil has an inductance of 2800 centimeters, the proper height of the aerial wire would be 100 feet, if the most effective wave radiation is to be secured.

The inductive system comprises a closed oscillating electric circuit and an open one, which are inductively connected by means of an oscillation transformer. The terms open and closed oscillating circuit require some explanation. If a condenser, such as a Leyden jar, has an inductance or coiled wire connected to one coating, and if a spark gap or pair of spark balls is placed between the other coating and the free end of the inductance, then we have a capacity, inductance, and spark gap in series. Such a circuit is called a closed oscillating circuit. In it we can set up electrical oscillations, but these cannot impart their energy freely to the æther in the form of electric waves. In order that radiation may take place, there must be a considerable separation between the ends of the circuit which comprises the oscillating circuit. Thus, if we set up oscillations in a straight metal rod, we have free radiation from the ends; but if we bend the rod round into a nearly-closed ring, so as to make what is called a Hertz detector, the ring now becomes a poor radiator of electric waves.

Suppose, then, that we have a straight wire or rod like a lightning conductor, and that between its lower end and an earth plate we insert one coil of a sort of air core transformer, the other coil being the inductance in a nearly-closed oscillatory circuit (see Fig. 4); we then have a closed and open electric circuit inductively coupled.

Now the rod and coil in series with it possess inductance, and the earthed rod or aerial has capacity with respect to the earth; hence it has a certain natural time-period of electrical oscillation.

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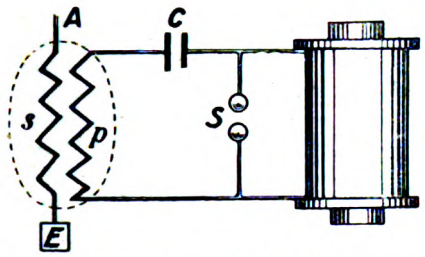

FIG. 4.—ARRANGEMENT OF CLOSED AND OPEN, OR RADIATIVE OSCILLATORY CIRCUITS, INDUCTIVELY COUPLED.

C, Condenser; S, Spark Balls; I, Induction Coil; E, Earth Plate; T, Oscillatory Transformer; p, primary; s, secondary.

If we so adjust the time-periods of the open and closed electric circuits that they are identical or in harmonic relation to one another, we have what is called a pair of tuned circuits inductively coupled, one of which is a good radiator, and the other a poor one, taken by itself.

If oscillations are set up in the closed circuit by connecting its spark balls to an induction coil or suitable high tension transformer, we have then a powerful arrangement for producing trains of electric waves.

Most modern wireless telegraph transmitters consist of an arrangement of the above kind. In order to tune the two circuits, there must be adjustable inductances in both the circuits, and by varying these the exact syntony between the inductive circuits is created.

There is a third method for producing electric waves, in which only one circuit, *viz.*, an open one, is employed. In one form this is due to Hertz, and in another to Marconi.

Hertz's original radiator consisted of a pair of insulated metal plates having short rods attached to them, these rods being terminated by spark balls. These plates are held in the same plane with the spark balls adjacent (see Fig. 5). If, then, an induction coil has its secondary terminals connected to these spark balls, when the coil is in action electric waves are radiated from the plates.

In this case the two insulated plates constitute the plates of a condenser widely separated. The attached rods have inductance and, therefore, form an oscillatory circuit of which the ends are widely separated. Marconi devised another form of circuit, consisting of an insulated vertical wire called an *aerial* or *antenna*. This is attached to one of a pair of spark balls forming the terminals of the secondary circuit of an induction coil. The fellow ball is connected to the earth (see Fig. 6). This aerial is, in fact, one surface of a condenser of which the other plate is the earth. When the coil is in action the rod is first charged up to a high potential; then, when the limit is reached at which the air insulation between the balls breaks down,

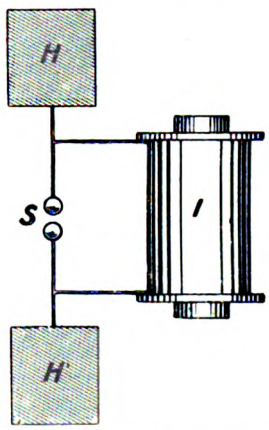

FIG. 5.—HERTZ OSCILLATOR OR RADIATOR.

H, H, Plates; I, Induction Coil; S, Spark Balls.

we have a discharge which is oscillatory in character, and at the same time we have electric radiation sent out from the wire. The characteristic quality of these open circuits is the extreme ease with which they radiate, so much so that the electric oscillations are confined to a very few periods. The store of electric energy in the charged wire is small,

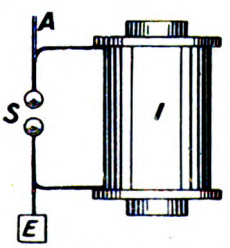

FIG. 6.—MARCONI AERIAL RADIATOR.

A, Aerial Wire; E, Earth Plate; S, Spark Balls; I, Induction Coil.

and it is all conveyed away by the æther in a very few oscillations. The capacity of an aerial wire 0·1 inch in diameter, and 100 feet in length, is about $\frac{1}{5000}$ of an microfarad. Hence, if such a wire is charged to 30,000 volts, equal to a spark between small balls about 1·5 centimeters in length, the energy stored up in the wire is only one-quarter of a

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joule, or about three-sixteenths of a foot-pound. There is, therefore, not much energy to draw upon, and the oscillations are necessarily soon quenched. An aerial or Hertz oscillator resembles, therefore, a small black vessel full of hot water. It is a good radiator, has a small store of heat, and therefore soon cools.

When, however, we have a closed circuit consisting of a large condenser, and allow the energy stored in this to radiate by means of an inductively coupled aerial, we have the means of producing very persistent oscillations.

In connection with this subject the measurement of the wave length of the waves sent out from such transmitters as above described is very important. It is necessary to be able to measure the lengths of waves emanating from any wireless telegraph transmitter. The author has lately bestowed considerable attention upon this practical problem, and has devised an instrument which he calls a Kummeter (from the Greek κυμα = a wave) for this purpose.

The instrument consists of a long helix or spiral of fine silk-covered copper wire wound in one single layer on an ebonite rod or tube (see Fig. 7). These windings are placed in close contiguity. This helix is supported in a horizontal position on insulating stands at a height of a couple of feet or so above the table. One end of this helix is provided with a small metal plate which is placed in apposition to another similar metal plate carried on an insulating stand, the two plates forming an air condenser (see Fig. 8). On the helix slides a metal saddle having a lining of tin foil. This saddle is connected by a flexible wire with the earth. In addition there is a screen of wire gauze which has a hole in it, and this is placed at the end of the helix near to the metal plate. If, then, we desire to determine the wave length of the wave given out by any wireless telegraph transmitter, arranged on the inductive system, we set up this kummeter near to it, and connect the insulated metal plate to one end of the primary coil of the oscillation transformer, the other end being connected to the earth. Hence, when the transmitter is in action at each spark rapid oscillations of potential take place in the plate attached to it, and these act by electrostatic on the other plate attached to the kummeter and cause electromotive impulses to act on one end of the helix. These impulses create stationary electric waves in the helix provided that the saddle piece is placed in certain positions. To ascertain these positions the following procedure is adopted:—Certain vacuum tubes of the kind employed in spectrum analysis are provided, and these are filled with the rare atmospheric gas called Neon, discovered by Sir William Ramsay. Such tubes have been found by the author to be extremely sensitive to the presence of rapidly alternating electric force.

If the Neon vacuum tube is held with its axis perpendicular to the above-mentioned helix, when it is connected as described with a wireless telegraph transmitter in action, then the tube glows with a bright orange light. If then the saddle is moved about it is possible to find such a position of it that when the

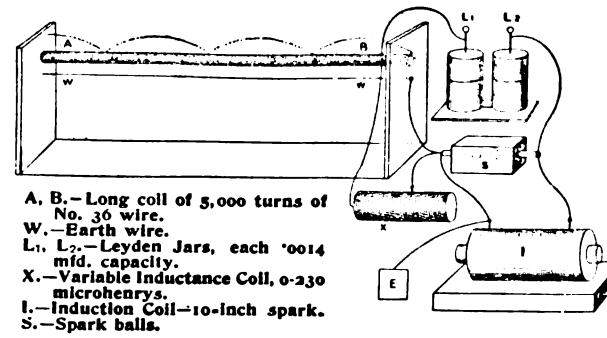

FIG. 7.—THE KUMMETER.

Neon tube is held over the saddle it is not illuminated. When moved to a position one quarter of the way towards the end condenser plate it glows brightly, when half-way is again extinguished, and when three-quarters of the way again bright, and when held against the screen it is again dark.

When this is the case it shows that we have so adjusted the active length of the helix that one complete wave of a stationary electric wave is formed upon it. The electric impulses applied to the plate have set up stationary vibrations in the helix, just as stationary ærial waves are set up in an organ pipe. If then we measure the distance from the saddle to the end plate we know the wave length of the stationary wave on the helix corresponding to the particular frequency of the transmitter. These vibrations travel along the helix with a definite velocity, and it can be shown by theory that this value of this velocity is obtained by taking the reciprocal of the square root of the product of

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the inductance of the helix and its capacity both per unit of length. The helix has a certain capacity with respect to the earth. Let this be numerically equal to C microfarads. Also the helix has a certain induction. Let this be L centimeters. Suppose the total length of the helix is l centimeters. Then the capacity in electromagnetic units is $C/10^{15}$ and hence the capacity per unit of length of the helix is $C/l\,10^{15}$. Accordingly the velocity V with which an electric wave travels along the helix is given by the expression

$$W = \frac{l\sqrt{10^{15}}}{\sqrt{CL}} \text{ cms/sec.}$$

For one of the helixes constructed by the author this velocity is 172×10^6 centimeters per second.

In all cases of wave motion the wave length λ, the wave velocity V, and frequency n are connected by the equation

$$V = n\lambda.$$

Hence if we know V and λ we can deduce n.

If then we ascertain for the helix used the capacity and inductance per unit of length, which can easily be done by laboratory measurements, and measure as above described the wave length on the helix, the quotient of the first by the second in centimeters second measure gives us the frequency of the electric oscillations being created by the transmitter.

The electric waves sent off from the transmitter into space travel with the velocity of light, which is nearly 1,000 million feet per second. Hence if we have the frequency n of these oscillations, the quotient obtained by dividing 1,000 million by n gives us the wave length in space of the wave sent out by the aerial attached to the transmitter. For example, in the case of the kummeter made by the author, the velocity along the helix is 172 million centimeters per second. Using it with a particular wireless transmitter, it was found that the wave length on the helix was eighty-five centimeters.

Hence the frequency of the oscillations of this transmitter is two million, and the wave sent out by its aerial is therefore 500 feet in length.

This kummeter is therefore of the greatest use in telling us at once the wave length of various wireless waves and enabling us to judge as to the wave lengths which are most effective under given conditions.

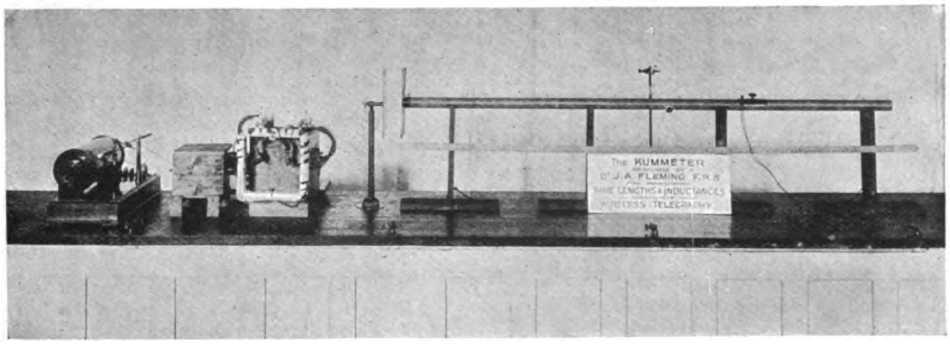

FIG. 8.—FLEMING KUMMETER FOR THE MEASUREMENT OF THE WAVE LENGTHS OF ELECTRIC WAVES USED IN WIRELESS TELEGRAPHY.

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DAMPNESS IN HOUSES: ITS PREVENTION AND CURE.

By RUFUS E. MARSDEN, Assoc. San. Inst.

ONE of the most vital requirements of a dwelling-house is that it shall be dry. To be dry it must be so constructed that it will resist all attempts of our variable climate to make it damp. The destruction of pictures, carpets, and furniture is only a small item of the ill effects that generally accompany the occupation of a damp dwelling; for injury to furniture can never be regarded so seriously as injury to health, and the premature shortening of life.

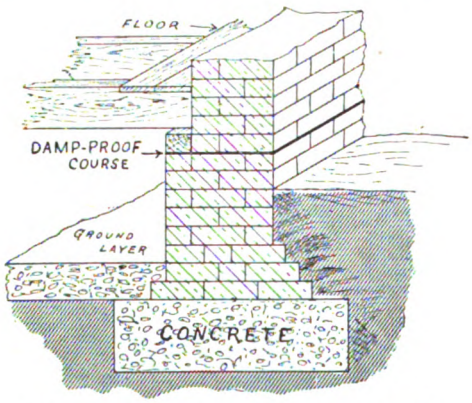

FIG. 1.—WALL WITH DAMP-PROOF COURSE.

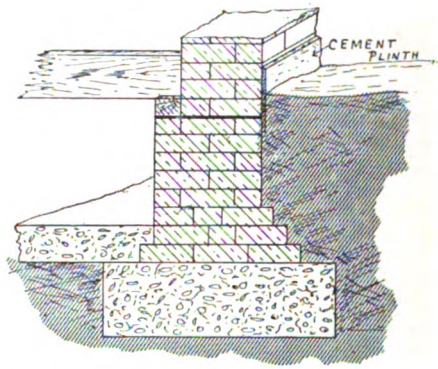

FIG. 2.—WALL WITH CEMENT PLINTH.

Pneumonia, rheumatic fever, neuralgia, and phthisis are a few of the more dreaded diseases to the development of which a damp environment seems favourable; and, in addition, there is always present a greater liability to the common cold, with its possibilities of leading to more serious complaints.

This being so, it is of general interest to know the methods by which we can prevent the entrance of this most insidious enemy—damp—into our houses.

All possible methods fall into two great classes: either that of prevention or cure. And while prevention is ever the best and safest course, yet a cure is always to be regarded as a blessing.

An eminent professor told his audience that they ought to thank the jerry-builder for making houses into which fresh air could always gain an entrance, no matter how much the inmates tried to exclude it by the use of draught preventers. But when suggesting that our thanks were due to the jerry builder, the professor forgot to mention that we could not feel thankful for the intrusion of damp.

Apart from bad design, bad work and inferior materials are responsible for dampness. Like the modern besieger, damp attacks our castles from above, below, and sideways. If the roof has a weak place our enemy finds it; if our walls are not what they should be, he knows it before we do; and if the upward path, from the soil on which the house stands, be not obstructed—well, that way in is as good as any. To prevent the damp from taking possession of our walls, by entering through the brickwork in contact with the ground, a damp-proof course must be inserted at a level of from three to six inches above ground line (Fig. 1). This damp-proof course can consist of sheet lead, asphalte, sheet bitumen, a double course of slates in cement, or stoneware slabs specially made for the purpose. In the majority of houses the damp-proof course is only a few inches above ground line, as it is necessary to place it beneath the level of the ground floor, as in Fig. 1. I was recently consulted in a case where a previously dry house became damp, and it was thought that perhaps the excessive rains at the early part of the year had been the sole cause; but on inspection I found that the surrounding

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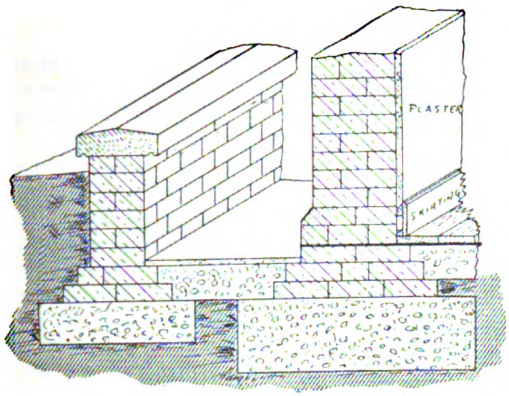

FIG. 3.—DRY AREA.

ground had been made up for garden purposes, so that the level of the earth was above the damp-proof course, and this had led to the mischief. An economical and yet satisfactory method of remedying this state of affairs, where it exists, is to dig the earth away from the walls of the house, and run a Portland cement plinth along the wall, extending from a few inches above ground level, to a short distance below the horizontal damp-proof course, as in Fig. 2.

In very wet subsoil the horizontal damp-proof course alone is not sufficient to keep the damp out of the dwelling; especially is this true when the lowest floor is below the outside ground level.

The best method of constructing a house in a damp situation is by building an open area, as shown in Fig. 3, all round the dwelling. Another method is to build the wall in two portions, with a cavity between, as shown in Fig. 4. This cavity should be drained and ventilated, but at the best it is not so good from many points of view as the open area. An economical way of keeping the wall dry is to render the surface of it, which is in contact with the ground, with Portland cement, or asphalte, the latter being preferable; or the cavity between the two walls in Fig. 4 can be made about one inch wide, and filled in with some damp-proof material, such as White's hygeian rock, or asphalte. A regulation properly imposed in London is, that the sites of all buildings shall be covered with six inches of good concrete. This has been shown in diagrams, Figs. 1–4, and it constitutes another barrier to the entrance of damp. But as concrete alone is not impervious, it is necessary, in very damp situations, to finish the top surface with either neat Portland cement or asphalte. Wherever it can be applied, asphalte renders a wall impenetrable to moisture. Callender's sheet bitumen can be used with like effect.

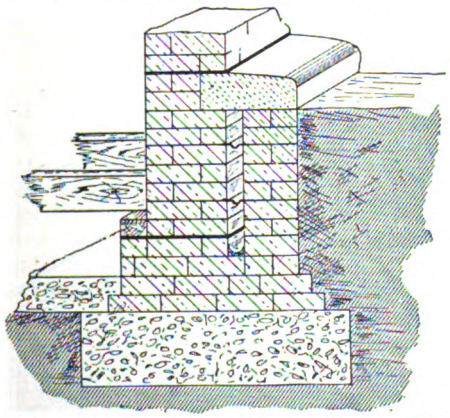

FIG. 4.—FLOOR BELOW GROUND LEVEL, WITH CAVITY WALL.

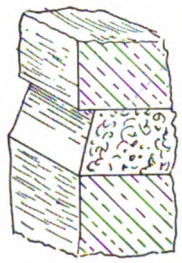

FIG. 5.
CORRECT FORM OF WEATHERED JOINT.

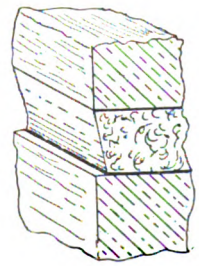

FIG. 6.
INCORRECT FORM OF WEATHERED JOINT.

To prevent damp from entering through the walls of a house, it is necessary that they be constructed of thoroughly sound materials; porous bricks and weak mortar readily absorb any moisture they come in contact with. The joints of the brickwork should receive attention, the best form of joint being that shown in Fig. 5, and known as a "struck" or "weathered" joint. Another form of the same joint not infrequently met with in practice is given in Fig. 6. This is obviously a bad method of forming the joint, as the small ledge at the bottom of the joint forms a resting-place for rain, instead of rapidly conducting the water off the joint.

A form of joint very popular with a certain class of builder is given in Fig. 7, and is known as "tuck pointing."

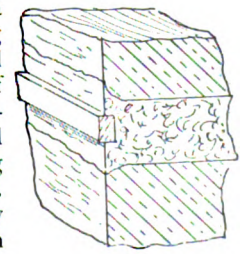

FIG. 7.
TUCK POINTING.

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This is usually adopted when the quality of the work requires disguising, because the whole surface is either rubbed over with a piece of soft brick of good colour, or a coloured wash is smeared over it, then a small white band of lime putty is stuck on to the centre of the hidden joint. This small band has the appearance of a neat white joint, and imitates one indication of good work. The white band is much better inserted as in Fig. 7, but this is not always done; and even when it is, the joint is not anything like so durable as the weathered joint. The only time when tuck pointing can be recommended is when the bricks have crumbled away at their edges, leaving very ragged joints. To make a lasting job, pointing should be done by raking out the joints to the depth of three-quarters of an inch, and then filling them in with good cement mortar, finished with a weathered joint.

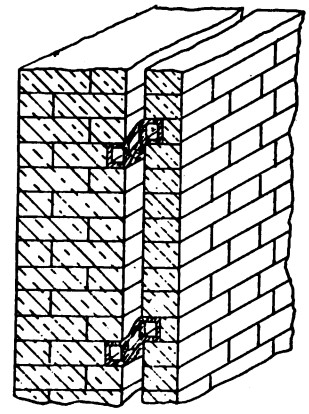

FIG. 8.
PORTION OF HOLLOW WALL.

In very exposed situations, where driving rains are prevalent, hollow walls are built. As shown in Fig. 8, these consist of two walls, with a cavity between them, the two walls being tied together with stoneware or iron ties. The thin wall faces the weather, and the cavity prevents the inner wall from getting damp. In walls so constructed care must be taken to prevent door and window frames from getting damp, owing to the moisture running down on the inside of the outer wall. This can be accomplished by the provision of a small lead gutter, as in Fig. 9, placed above the arches over the openings.

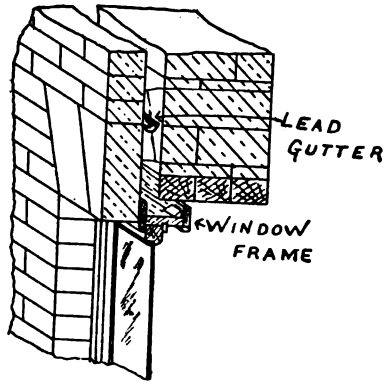

FIG. 9.—HOLLOW WALL OVER WINDOW-FRAME.

In cavity walls, the cavity helps to preserve a more equable temperature in the interior of a house, besides preventing dampness.

To prevent walls built in one piece from becoming damp, after the house has been built some time, several methods may be adopted. A preparation known as "Fluate," sold by the Bath Stone Firms, Limited, has proved itself to be a real preservative, and makes the surface to which it is applied damp-proof. The liquid can be directly applied to stonework, while for brickwork it is only necessary to use a dressing of "Avant Fluate," and then a dressing of "Fluate of Magnesia." There are patent silicate paints on the market for the same use; but two coats of Portland cement wash will form an effective cure of damp walls.

Other remedies are:—the application of three coats of boiled linseed oil; paraffin paint, prepared by dissolving one part of paraffin in two to three parts of coal-tar oil, at a moderate heat, oil being mixed with it to prevent it from quite congealing when cool; and hanging tiles, or a rendering of Portland cement stucco. The tiles used should be well burnt, so that the exposed surfaces are impervious to moisture; they can either be fixed by nailing direct to the brickwork, or battens may be first nailed on, as shown in Fig. 10; slates may be used instead of tiles. To keep the face of the wall as free from wet as possible, all window-sills should stand out beyond the face of the wall, and have a small groove, known as a "throating," run along their projecting under

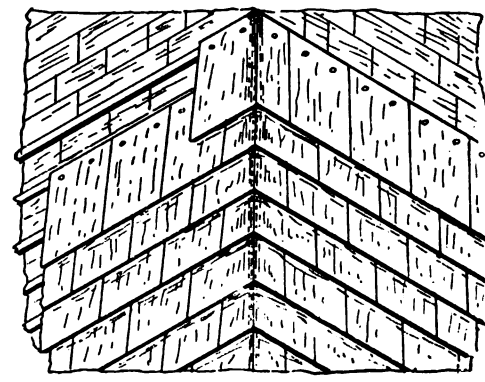

FIG. 10.—TILE-COVERED WALL.

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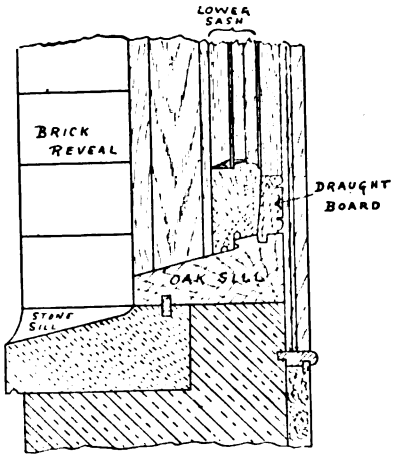

FIG. 11.—BOTTOM PART OF BEST FORM OF SASH.

surface, as in Fig. 11. Cornices and string courses should project and be throated in a similar way, and the joints in rain-water pipes should be secure. Only quite recently I saw an example of a damp wall caused by a small zinc rain-water pipe, which had been broken off a short distance from the ground, discharging against the brickwork and above the damp-proof course. The remedy was simply the mending of the rain-water pipe, so that it discharged away from the wall.

The slates and tiles on roofs should be of good quality and so laid that the rain is quickly conducted into the gutters, which must be kept clean. It should be borne in mind that a straight roof can be more easily made and kept water-tight than can a roof cut up into numerous surfaces and angles. As regards the windows, the ordinary "guillotine" sash that slides up and down in two pieces is most easily made water-tight. In Fig. 11 the bottom part of the best form of such a sash is shown; a window board has been fixed to the lower end of the frame, so as to permit the lower sash to be opened for ventilation purposes without causing a draught. When the lower sash is raised nearly to the top of the window board fresh air is admitted between the two sashes, thus giving ventilation, even in windy weather, without draught.

For pleasantness the ordinary guillotine sash does not compare with the casement sash in fine weather; and when the casement is made to open outwards it can be rendered water-tight in the manner shown in Fig. 12.

For convenience of cleaning it is desirable that casements should open inwards, and other circumstances sometimes demand it; but casements so opening are less likely to be water-tight. In Fig. 13 one of the methods by which this joint is made most satisfactorily is shown; the hollow groove in the sill should have a small copper pipe fixed into the sill,

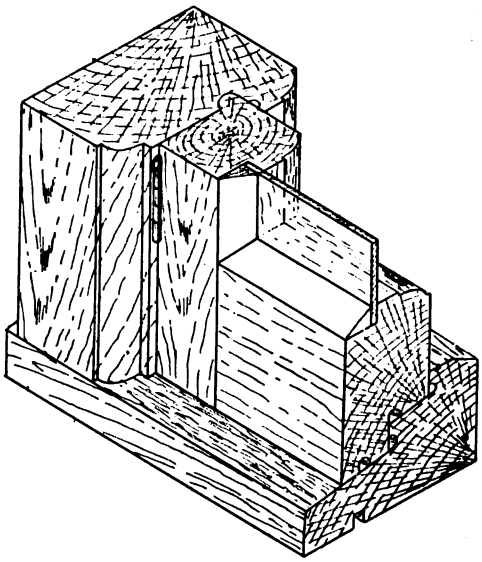

FIG. 12.—WATERPROOF CASEMENT.

connected with it so that water getting into this groove may find its way out.

The joints between the bottoms of doors and the door sills may admit the rain in exposed situations. To remedy this a weather board can be fixed on to the lower part of the door, so that any water running down the face of the door is conducted away from the joint between door and sill.

A metal water bar can be inserted in the sill, when it happens to be of wood, and the bottom edge of door rebated to fit over it.

A little attention to details such as those mentioned will do much to make a house comfortable; and in conclusion it must be pointed out that all gutters and water-pipes should be periodically attended to, so that they may be kept quite free from obstruction.

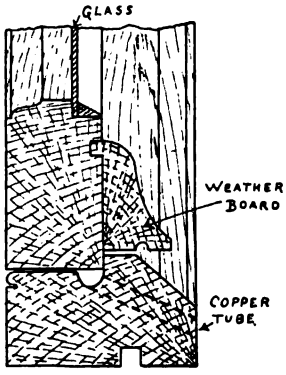

FIG. 13.—CASEMENT OPENING INWARDS.

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THE PREPARATION OF ENGLISH BEERS.

By JAMES GRANT, F.I.C., F.C.S.

Historical.

OSIRIS, the friend of Mizraim, grandson of Noah, and the first monarch of Egypt (probable date 2190 B.C.), is credited with the invention of an intoxicating liquor from corn. This beverage was very probably a form of barley wine, or unhopped beer. Long before the time of the historian Tacitus, beer appears to have been the common drink of the inhabitants of Europe. Tacitus declares that the Teutons (Germans) were much given to drunkenness, and that they prepared an alcoholic beverage from barley or wheat. Pliny, in the first century A.D., states that the people of Western Europe frequently intoxicated themselves by means of moistened corn. Such a beverage was the *zythum* of the Egyptians, the *celia* or *cerea* of the Spaniards, and the *cervisia* of the Gauls, in these early times.

After the introduction of agriculture into Britain by the Romans, ale and beer became the common drink of the people, and apparently replaced mead. According to Isidorus, in the early part of the fifth century the Celtic and Teutonic nations made their ale as follows :—

The grain was steeped in water and made to germinate, then dried and ground; after which it was infused with a certain quantity of warm water, and after being fermented produced a pleasant, warming, strengthening, and intoxicating liquid. This ale was mostly prepared from barley; but wheat, oats, and millet were frequently added. It, however, contained no hops. Between 1180—1540 A.D., the monasteries were famed for possessing the best ale, which they brewed for themselves with great care and skill.

In 1251, an assize for bread and ale was struck, which settled the price as follows :— "A brewer may sell two gallons of ale for a penny in cities, and three or four gallons for the same price in the country."

In 1471, the price of best ale was three-halfpence per gallon. About this time hops began to be used in Germany for the purpose of imparting a bitter, aromatic taste and stimulating effect to beers and ales.

During the reign of Henry VIII., hops were introduced into England from the Netherlands, for a similar purpose; but for many years their use was forbidden by law.

The first treatise on the production of beer was possibly that of Basil Valentine.

In 1585, a Bohemian, Thaddeus ab Hayck, published a work entitled: "De Cerevisia ejusque conficiendi ratione, natura, viribus et facultatibus." Although consisting of but fifty pages, this little book is characterised by its clearness, accuracy and simplicity.

In the early part of the eighteenth century, Combrune, a London practical brewer, published: "The Theory and Practice of Brewing," a book which has gone through many editions, and for a century was considered the standard work on the subject.

Definition of Beer.

Beer is a beverage produced by alcoholic fermentation from a hopped infusion, either of malted cereals (especially barley) or with an addition of unmalted grain as *grits*, or prepared cereals as *flakes*, or *sugars*.

The word "beer" is probably of Hebrew origin, coming from the word, דֹּר, corn, which has a sound somewhat resembling *tre* in metre. This passed through the Phœnician into the Anglo-Saxon "bepe," barley. This Saxon word has been retained in modern times, for the four-rowed barley (*Hordeum vulgare*) is known as *bere* or *bigge*.

During the Middle Ages the word beer was frequently written "bere." From the earliest time beer has been made from barley.

The Latin word *cervisia* (beer or ale) is derived from Ceres, the goddess of corn.

The word "ale" probably takes its origin from the Danish "oela."

From ancient times, the present popular beverage has been undergoing so many changes that it is impossible to draw a line fixing the actual meaning of beer and so distinguishing it from an adulterated article. It has been shown that barley and wheat have been the base of beer; and as barley is the grain that was raised by Europeans through "the long course of ages," as the staple article of food, it was also the cereal employed in the production of beer. In modern times, the number of varieties of

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cereals used has been much increased, and in all civilised countries maize and rice have been generally introduced.

From the foregoing it may be seen that the expression "only pure beer is an all-malt beer" is untrue both actually and historically.

The Raw Materials Necessary.

The raw materials required in brewing are the grist-forming bodies and suitable waters.

The grist-forming bodies include all those compounds which, when infused with hot water, form the wort; and this being boiled with hops, cooled, and fermented with yeast, yields the alcoholic beverage, beer. The chief of these are malted grain, raw grain, gelatinised starch as flakes, torrefied grain, and sugars.

The grist materials are chiefly produced from the plants of the natural order of *Gramineae* or grasses.

Thus barley, the representative of the *Hordeum* family, is the chief grist substance in the form of malted barley; but maize, rice, rye, wheat, oats, millet, sugar and sorghum canes are all laid under contribution.

If examined carefully, a close relationship will be seen to exist between all the different members of the order.

All possess tufted roots, a number of stems springing from the tuft; all the stems are hollow and jointed, or possess nodes; all are protected by the split leaf-sheath which is fixed to the upper portion of the stalk by a band or ligule, and from which hangs the ribbon. Above this is the spindle, on which grow the flowerets, these developing into the ears of corn.

There are a number of species of barley and numberless varieties; but in England the two-rowed barley or *distichum* is the only one malted. The chief malting varieties are: Chevaiier, Kinver, Premier, Burton Malting, Standwell, Goldthorpe, Golden Melon, Golden Grain, Golden Drop, etc.

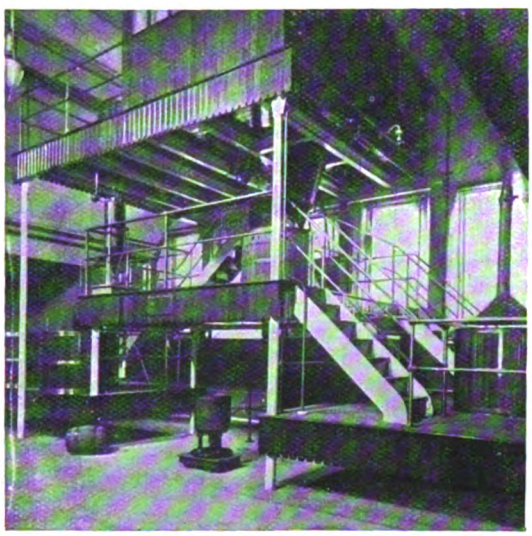

Fig. 1.—Model Brewery, Municipal School of Technology, Manchester.

Description of a Barleycorn.

A well-matured, perfect barleycorn is about one-third of an inch long, fusiform or spindle-shaped, rounded on the ventral or inner side, and rather flat on the outer or dorsal side. This latter side is protected by the pale or chaff known as the *palea inferior*, which develops into the *awn*. The inner side is covered by the *palea superior*. Down the centre of this inner side runs the deep ventral furrow, at the bottom of which is the basal bristle. Beneath the pales come the true skins of the barleycorn, *viz.*, the *pericarp* and *testa*. Below these again are rows of rectangular cells, full of granules of nitrogenous matter — the *aleurone* cells.

The interior of the corn consists of the albumen or *endosperm*, which is mainly starch: at the lower portion of the outer or dorsal side is placed the germ or embryo barley plant. This occupies about one-thirtieth of the whole corn. When fresh, as in new barley, this germ has a yellowish, buttery appearance; but after long storage it becomes darker, gradually loses its vitality, and then is useless for malting purposes.

Comparison of English and American Barley and Wheat.

Constituents.	English Barley.	Wheat.	American Barley.	Wheat.
Carbohydrates	64·85%	69·11%	69·45%	66·64%
Water. . .	13·06%	13·05%	10·85%	12·05%
Albumenoids .	11·46%	10·35%	11·00%	13·25%
Crude fibre .	7·28%	1·59%	3·85%	2·70%
Oil or fats .	1·03%	4·39%	2·25%	3·39%
Mineral matter	2·32%	1·51%	2·56%	1·97%

From the above figures it will be seen that cereals are composed of a small quantity of inorganic matter, a large proportion of organic non-nitrogenous compounds, and about 12 per cent. of nitrogen derivatives.

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Malting.

A barley suitable for malting should possess most of the following properties :—

A fine, delicate, slightly-wrinkled skin; thin husk, bright golden yellow colour; full and plump corns, free from black ends and centres; no mouldy, broken, or damaged corns; and a high germinative energy and capacity.

By *malting* is understood a germination under starvation conditions.

Its chief objects are to obtain :—

(*a*) A development of the *enzymes* or soluble ferments.

(*b*) A modification or rendering naked of the starch granules of the corn.

(*c*) Certain physical changes.

Summary of the Malting Processes.

The barley must be thoroughly cleaned and graded, then steeped until it has absorbed sufficient water to carry through the germinative processes.

Three systems of malting are in general use: the old Flooring, the Galland-Hennings, and the Saladin. The objects aimed at in each are very similar.

Flooring System.—In the flooring system, which gives the best results for brewing purposes, the barley is thrown, after steeping, into a long heap, and allowed to become warm, so as to start germination. This is the *couching;* and when the corns show signs of growth, as the appearance of a small white protuberance at the sharp or lower end of the corn, the couch is broken down and the barley spread on the growing floors in depths varying from four to seven inches to form the "first piece."

It is turned every few hours to equally diffuse moisture and air, and at the same time to prevent undue heating. During the growing the pieces are gradually worked down to the lower end of the floors. Sprinkling is occasionally necessary. Care is given to ensure good ventilation and an even temperature of about 54° F. The odour emitted by the growing barley resembles that of freshly-cut cucumber. While germination proceeds, the changes ensuing are of a very complex nature. The *physical* changes consist chiefly in the altered appearance of the starch internally, the development of the *acrospire* or plumule up the dorsal side of the corn under the *palea inferior*, and the growth of five or six bushy rootlets. The *chemical* changes are of a much more complex character. There is a modification of the starch granules by enzyme action: a large increase in the quantity of *diastase*, *cytase*, *proteolysts*, and other enzymes: the production of sugars, some of which are lost by germination: a modification, and loss of nitrogenous bodies through the rootlets.

When growth and modification are complete, the green malt, as the barley is now called, is withered, then conveyed to a malt kiln, dried, and cured. These latter operations are necessary in order to check further changes by enzyme action; to kill bacteria and other noxious organisms; to get rid of moisture; to restrict the diastase and other enzymes; and to give the malt its characteristics of flavour, colour, mealiness, friability, etc. The malt is now heaped up and allowed to cool, then cleaned, graded, and stored to permit of mellowing.

The chief points of difference between barley and the malt derived from it are: decrease in moisture, albumenoids, and

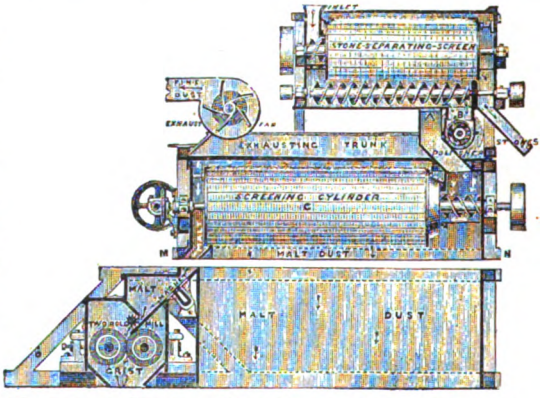

Fig. 2.—A Pair of Malt-Rolls, with Screening and Polishing Machinery attached.

mineral salts; increase in the percentage of sugars; modification of the starch and albumenoids. A 56 lbs. bushel of barley yields approximately a 42 lbs. bushel of malt.

Gelatinised starch is used in the form of flaked rice, maize, and wheat malts.

Flakes.—These are prepared by cooking pieces or grits of the cereals named, partially drying in order to condition, then passing between very smooth flaking rolls. Drying is completed, the materials packed in bags, and sent on to the market.

The chief objects in using flaked malts are: to obtain a beer that soon becomes brilliant, and an extract at a cheaper cost.

Grits.—Grits consist of small particles of raw grain, such as rice or maize; before they can be used in the mash tun with the malt grist they must be gelatinised in a converter.

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Sugars.—The following sugars are largely used in the production of the cheaper English beers and stouts :—

(*a*) *Cane sugar*, as derived from the sugar, sorghum, and other giant grasses or canes, and beetroots.

(*b*) *Invert sugars*, obtained from the various cane sugars either by acid or yeast inversion.

(*c*) *Glucoses* or corn sugars, derived mainly from maize starch. A quantity is also prepared from potato starch.

(*d*) *Starch transformation products*, sent out under different trade names.

(*e*) *Caramels*, prepared from various raw materials by heat action, and used chiefly in the production of porters and stouts.

Brewing Waters.

Water is used for a variety of purposes in the brewery. Among the more important applications are :—

(*a*) Steam raising or boiler feeding.

(*b*) Cleansing both the brewery and plant.

(*c*) Cooling the hot worts.

(*d*) Mashing, or the actual production of the worts.

For boiler-feed purposes, the water should be as free as possible from hardening substances, and especially from compounds such as gypsum, epsom salts, lime, and magnesium chlorides, and an excess of alkaline salts, as these latter cause priming and its consequent troubles in the boilers.

For cleansing and cooling almost any form of water, provided that it contains no noxious ingredients, may be employed.

For mashing or wort production certain natural waters are very suitable. Thus, the springs and wells around Burton-on-Trent from the Keuper and New Red Sandstone beds are admirably adapted for brewing pale and stock ales. Such are of a saline and gypsum type of hard water.

For the production of stouts and black beers, waters of a calcareous nature are required. Such may be found in the River Liffey at Dublin, also in the chalk districts of the Thames basin. Hence, in Burton are Bass, Allsopp, Worthington, and other pale ale brewers; in Dublin, the far-famed Guinness stout breweries; in London, Whitbread, Hoare, and other celebrated stout and porter brewers.

Other natural waters, of types unlike those quoted, require treatment, such as the addition of suitable hardening salts. This is frequently spoken of as "burtonising."

The following analyses show the composition of three types of waters; all the figures given represent grains per gallon.

Pure Drinking Water. (Manchester).		Pale Ale Water. (Burton).		Stout Water. (London).	
$CaSO_4$.	1·753	$CaSO_4$.	79·89	$CaCO_3$.	15·29
$MgSO_4$.	0·594	$MgSO_4$.	8·55	$MgCO_3$.	0·76
$MgCl_2$.	0·516	$CaCO_3$.	6·27	$CaSO_4$.	4·31
NaCl.	0·499	$MgCO_3$.	2·89	K_2SO_4.	0·78
SiO_2.	0·239	K_2SO_4.	0·96	$Mg(NO_3)_2$	0.96
Organic	0·733	Na_2SO_4.	8·69	$CaCl_2$.	0·63
		NaCl.	11·79	NaCl.	1·38
		SiO_2	0·57	SiO_2.	0·34
	4·334		119·61		24·45

Thus a Manchester drinking water contains 4·334 grains per gallon, a Burton well 119·61 and a London well 24·45 grains per gallon.

Brewery Plant.

The plant and its arrangement depend very largely on the style, type and size of the brewery. In any case, due attention must be paid to convenience, simplicity, ease of control, cleanliness and facility of working.

The tower or gravity brewery is one of the best for small concerns; but with a large-sized plant much depends on the personal element in arranging the various vessels and machines. There are, however, certain factors which must always guide those in authority. For example, it is permissible to pump wort only between the mash-tun and the coolers. Outside of these limits there would be grave risks of serious contamination.

In a tower brewery, the necessary plant might be arranged somewhat as follows :—

Top floor might contain the hoist, hot and cold liquor (water) tanks.

The next lower could contain the malt-rolls, stores for malt—say a week's supply—sugar and flake room; and in the floor the grist case. The floor below should contain the mash-tuns on a raised platform, the raw-grain converter, if any, and the coppers halfway through the floors. In an adjacent room stores for grits, hops, etc.

The first floor may contain the hop-back, lower half of the coppers, and in a branch room, the coolers. The ground floor might be occupied by cask-washing plant, the refrigerator, and adjoining, the fermentation room on the north side of the brewery under the coolers.

(*To be continued.*)

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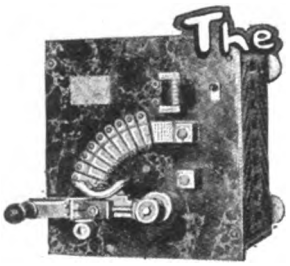
STARTING RESISTANCES FOR SHUNT MOTORS.

By GEORGE W. O. HOWE, M.Sc., Whitworth Scholar.



The current flowing through the armature of a shunt motor is expressed at any moment by the formula

$$C = \frac{E - e}{R},$$

where E is the pressure on the mains, e the back pressure generated by the rotation of the armature, and R is the total resistance. ($R = R_a + R_e$, where R_a is the invariable armature resistance, and R_e is the external resistance, introduced by means of starters or main current regulators.) When the motor is at rest $e = o$, and $C = E/(R_a + R_e)$. When running normally at full speed, the external resistance being all cut out, we have $C = (E - e)/R_a$. If the armature at rest be connected directly to the mains, we have $C = E/R_a$, and as R_a is generally very small, the current would be so large that the armature would probably be ruined.

When starting a motor, it is, therefore, necessary to put a considerable resistance in series with the armature, which resistance must be gradually reduced as the speed increases. In a shunt motor with practically constant field, the torque exerted by the motor is proportional to the armature current, quite irrespective of the speed at which the motor may be running; hence, the armature current is dependent only on the torque of the load, and we may write $T = kC$, where T is the torque due to the load on the motor, and k is a constant depending on the field strength and the armature winding.

The back E.M.F., e, is proportional to the speed, and we may write $e = k'\omega$, where ω is the angular velocity of the armature, and k' is a constant depending on the field and on the armature winding. The output of the motor, $P = T.\omega = kC\omega$; but P is also approximately equal to Ce, whence $P = k'C\omega$. We see that k and k' are identical, and we can, therefore, omit the dash.

$$\text{Now } C = \frac{E - e}{R}; \therefore CR = E - e,$$

$$\text{or } \frac{T}{k} R = E - k\omega,$$

$$\text{and hence } \omega = \frac{E}{k} - \frac{TR}{k^2} \quad . \quad . \quad . \quad (1);$$

that is to say, for a constant load producing a torque T, each value of R has a corresponding speed at which the motor will run, and the larger R is made the lower will be the speed. We see, further, that if R is very small, which is the case when the motor is running directly off the mains, considerable changes in the load T will have but a small effect on the speed; whereas, if R is made large, by introducing resistance in the armature circuit, the speed will be greatly affected by variations in the load. This is a well-known fact in connection with shunt motors having speed regulators in the main circuit.

We may now look more closely into the changes occurring during starting. Imagine the motor at rest and fully loaded; the armature current must be at least equal to the normal full load current before the motor will start; and, owing to static friction, it will probably need to be considerably greater. A starting resistance could be made so that on the first step the current $C = E/(R_a + R_e)$ is more than enough to just move the armature. The motor will run up to some slow speed determined by the formula (1), the current gradually falling to its normal full load value. The starting switch is then moved on to the next point, suddenly cutting out a section of the external resistance, and the current jumps suddenly to a value corresponding to the decreased resistance, but then gradually decreases to its former value, as the speed rises to its new value. This process is repeated until all the external resistance has been cut out, and the motor rises to its full speed as given by the formula

$$\omega = \frac{E}{k} - \frac{TR_a}{k^2}.$$

It is important to notice that the time taken to start depends on the inertia of the moving parts; if this were negligible, the motor would instantly attain full speed, although starting under full load. The resistance of the starter and the number of steps depends on the voltage of the mains, on the armature resistance, and on the load. The current-carrying capacity of the resistance depends, on the other hand, on the inertia of the moving parts, and the frequency of starting. Let us consider, in the first place, the resistance and its subdivision into steps. The first point on which a definite decision must be made is the maximum

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current allowable during the start. If we keep our eye on the main ammeter during the operation, we shall see that the current jumps suddenly on moving from step to step, the variation depending on the number of steps. The ideal starter would be a long slide wire, by means of which the resistance could be gradually reduced, and the ammeter kept steady at, say, 50 per cent. above the normal full load current, until all the resistance was cut out. In actual practice such a slide wire is impracticable, and the resistance has to be decreased in steps. At each step the current rises to a maximum, and then sinks to its minimum value. In a properly designed starter, operated in a skilful manner, these maxima and minima of current should be the same for every step. If this be so, we have a near approximation to a constant acceleration during the whole start. Suppose we decide that the current shall fluctuate between 1·15 times the normal and twice the normal current, these being suitable figures for a full load starter. Much time would be lost if we waited on each step until the current fell to the normal value, as it falls at first rather quickly, but afterwards more slowly. The total resistance should then give, on switching in, twice the full load current, and can thus be easily calculated: $R_a + R_e = E/(2 \times \text{normal current})$. How shall we subdivide this resistance?

Let the combined resistance of the armature and the step last cut out be R_1, the last step alone r_1, the next step r_2, and the combined resistance when on this step, R_2, and so on. Then we have $R_1 = R_a + r_1$; $R_2 = R_a + r_1 + r_2$ etc., and, finally $R_n = R_a + r_1 + r_2 + \ldots + r_n = R_a + R_e$, where n is the number of steps. Let $\lambda = \frac{\text{max. current}}{\text{min. current}}$ during the start; I have given above $\frac{2\cdot0}{1\cdot15} = 1\cdot74$ as a suitable value of λ. Then

$$\frac{R_1}{R_a} = \frac{R_2}{R_1} = \ldots = \frac{R_n}{R_{n-1}} = \lambda;$$

$$\therefore \lambda^n = \frac{R_1}{R_a} \times \frac{R_2}{R_1} \times \ldots \times \frac{R_n}{R_{n-1}}$$

$$= \frac{R_n}{R_a} = \frac{R_a + R_e}{R_a},$$

whence, $n = \log\left(\frac{R_a + R_e}{R_a}\right) \Big/ \log \lambda$.

Thus n is easily calculated; we should make our starter with the most convenient whole number of steps larger than the calculated value of n.

Starting with R_a, the total resistance increases in a geometrical progression with the ratio λ. This is shown graphically in Fig. 1, where the ordinates represent the total resistances at the various points, and the resistance of any step is given as the difference between successive ordinates.

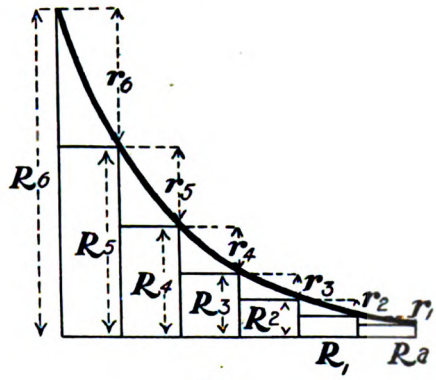

FIG. 1.

Another graphic method, more simple and interesting than this, is shown in Fig. 2. The horizontal base A C is made to represent, to some convenient scale, $R_a + R_e$, and is divided at B, so that A B = R_e and B C = R_a. Verticals are drawn through A, B and C, and are cut by horizontal lines at heights above AC representing to a convenient scale the maximum and minimum currents during starting; thus B D = maximum, and B E = minimum current. Join C E and produce to G; drop a perpendicular G H J, join C H and produce to K; drop a perpendicular K L M, and so on, until we finally arrive at or near the point S. The external resistance A B is thus divided into steps, which are evidently in accordance with the theoretical requirements, for $\frac{R_1}{R_a} = \frac{JC}{BC} = \frac{JG}{BE} = \lambda$, and similarly $\frac{R_2}{R_1} = \frac{MC}{JC} = \frac{MK}{JH} = \lambda$, and so on for all the steps. This diagram is very easily made, and has many points of interest.

Let ω = normal speed at full load.

ω' = no load speed, neglecting armature resistance.

and ω_1 = speed at moment of cutting out the starting resistance.

then $E = k\,\omega'$;

$$\therefore \omega' = \frac{E}{k} = \frac{C_{max}(R_a + R_e)}{k},$$

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$$\omega = \frac{C_{max}(R_a + R_e) - C_{nor} R_a}{k},$$

and $$\omega_1 = \frac{C_{max}(R_a + R_e) - C_{max} R_a}{k};$$

hence, $$\omega' : \omega : \omega_1 = (R_a + R_e) : (R_a + R_e) - \frac{C_{nor}}{C_{max}} \cdot R_a : (R_a + R_e) - R_a$$
$$= AC : NF : AB,$$

where F is the point in which the horizontal line NT, at a height representing the normal current, cuts the line CD. Again, at the moment of cutting out the first step r_n, the speed ω_n is equal to $(E - C_{max} R_{n-1})/k$; that is, $(C_{max}(R_a + R_e) - C_{max} R_{n-1})/k$; hence the speed ω_n is proportional to the length AP, which is equal to $R_a + R_e - R_{n-1}$. In a similar manner it could be shown that at the moment of cutting out any step, the speed is proportional to the total resistance cut out up to that point; that is, to the distance from A along AC. With our ideal slide wire starter, the speed could be plotted vertically on a resistance base such as we have in Fig. 2, and would evidently be a straight line

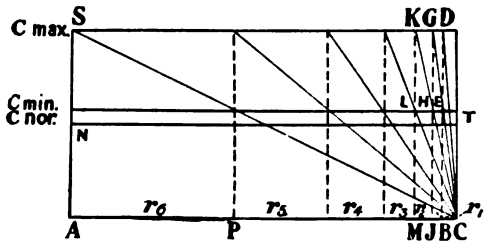
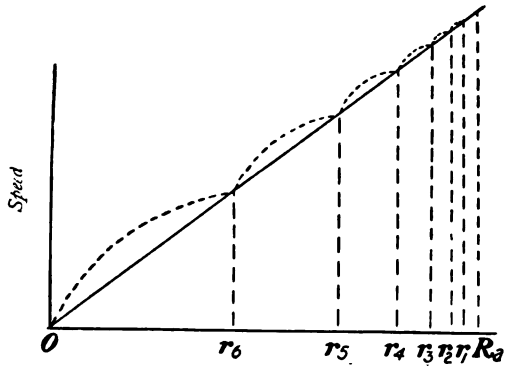


FIG. 2.

through A. The current being constant, the torque and, therefore, also the acceleration would be constant, as shown in Fig. 3; but with constant acceleration the speed-time curve is a straight line through the origin,



Resistance or Time.

FIG. 3.

and we can, therefore, look upon our base in Figs. 2 and 3 as a time base. With a step-by-step starter, the speed-time curve is not exactly a straight line, owing to the variations of current and, therefore, of torque and acceleration. The effect will be as shown dotted in Fig. 3, the slope, which represents the acceleration, gradually decreasing during the time spent on each step. The current-time curve will also be modified as shown in Fig. 4.

We see, therefore, that the time spent on each step is proportional to the resistance of that step, so that as much time should be spent on the first step or two as on the whole of the remaining steps.

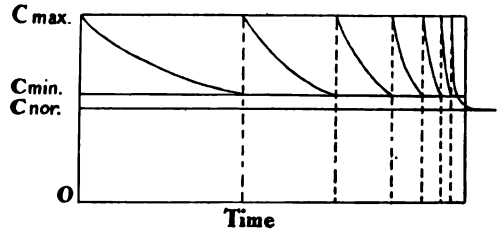


FIG. 4.

We have assumed, so far, that the current allowable on first switching in, is twice the normal full load current. This would be quite correct, if the motor always started under load. If, however, there is a possibility of the motor being started light, this current may be rather high, causing a very sudden start. This may be prevented by providing the starter with a preliminary step, bringing the current down to the normal full load value. When starting under load the motor will not move on this step, and the attendant will immediately move over to the next. This preliminary step may, therefore, be made very light, without much danger of burning out. Having determined the resistance of each step, the next point is the size and amount of resistance material to use, to insure the temperature keeping within specified limits. This depends on the time, during each start, that any step is under current, and also on the frequency of starting. The latter point can only be determined from a knowledge of the conditions under which the starter is to be employed, some being used once a day and others every minute. The duration of each start depends, as we have already seen, on the inertia of the masses which have to be set in motion. If the motor starts under full load, the normal full load current is required to give the load torque, and only the excess

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current is available for accelerating torque. With the values which we have assumed for the starting current, the accelerating torque will thus vary between 15 and 100 per cent. of the normal full load torque. When starting up light, nearly all the torque produced by the armature current is available for acceleration. A fully loaded motor may start much more readily than an unloaded motor carrying a heavy flywheel. The neglect of this point has been the cause of much trouble with motor-starting resistances.

Let us now look more closely into the time required for starting under any given conditions. Let I be the "equivalent moment of inertia" of all the masses to be set in motion, including the armature itself. By equivalent moment of inertia is meant the moment of inertia of a flywheel, which, when fixed on the motor shaft, would produce the effect that is actually produced. If a flywheel, with moment of inertia I′ is driven from the motor by belt or gearing at a speed ω', it is equivalent, so far as the energy required to start it is concerned, to a moment of inertia $I = I' (\omega'/\omega)^2$ on the motor shaft. If the rotation of the motor is converted into rectilineal motion, as in motors for driving planing machines, then the mass m to be set in motion must be considered as fixed at a radius r to the motor shaft, the value of r being chosen so that the assumed peripheral speed is equal to the actual rectilineal speed; then the equivalent moment of inertia is equal to mr^2. Let C be the mean value of the available accelerating current during the start, and T the torque it produces; then $T = I\frac{d\omega}{dt}$. Hence the angular acceleration, $\frac{d\omega}{dt}$ is readily found; it is the increase of angular velocity per second. The time in seconds required to attain a speed ω is therefore $\omega/\frac{d\omega}{dt}$, or $\omega I/T$, or $\omega I/k C$. We see that the time required for starting is proportional to I and inversely proportional to C. Substituting for k from the formula $e = k\omega$, we find the time to be $\omega^2 I/e C$, which is very nearly the same as $\omega^2 I/EC$. An example will make the method clear.

A 40 horse-power, 440 volt motor, running at 650 revs. per minute, took a full load current of 79 amperes. Its armature had a moment of inertia of 36×10^6 gram. cms.^{2}, but was directly coupled to a similar armature, so that I was 72×10^6 units. 650 revs. per minute corresponds to an angular velocity of $2\pi \times (650/60) = 68$ radians per second. The full load, 40 h.p. $= 40 \times 746 = 29840$ watts $= 29840 \times 10^7$ dergs per second.

$$T = \frac{\text{work per second}}{\text{angular velocity}} = \frac{29840 \times 10^7}{68}$$
$$= 440 \times 10^7 \text{ dyne cms},$$

which is the normal torque corresponding to an armature current of 79 amperes. The mean current during the start was about 91 amperes, and the accelerating current therefore 12 amperes. The full load was kept on by means of a brake. The accelerating torque was, therefore, $440 \times 10^7 \times \frac{12}{79} = 66{\cdot}5 \times 10$ dyne cms., and the time of starting

$$\frac{\omega I}{T} = \frac{68 \times 72 \times 10^6}{66{\cdot}5 \times 10^7} = 7{\cdot}4 \text{ seconds},$$

which is in good agreement with the actual results of tests made.

Had the total moment of inertia been ten times instead of twice that of the armature, we should have required 37 seconds. In some cases, such as large centrifugal separators, the time required is much longer.

Had our motor been unloaded, nearly the whole current would have been available for acceleration, and the time would have been reduced to about a second, could the starter have been moved thus rapidly.

The time of starting generally assumed in designing the resistance is about half a minute, anything requiring a longer time being looked upon as a special job. Only the smallest step is under current during the whole of this time, the time for the others being proportional to the distance from A in Fig. 2. The resistance material of the larger steps can be overloaded more than that of the smaller ones. The allowable overload depends of course on the frequency of starting, the thermal capacity of the resistance, and the material—such as sand, porcelain, or asbestos—in direct contact with it; and on the rate of cooling. This allowable overload can only be determined with any degree of certainty from numerous experiments with the type of resistance used, and is beyond the limits of this article.

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THEORY OF STRUCTURAL DESIGN.

PART X.—PILLAR FORMULÆ.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

REFERENCE to the previous issue of this magazine will show that the square of the radius of equivalence (or gyration) is involved in the pillar formula there given. This formula will now be compared with others involving the square of the least diameter, taking no account of the disposition of the cross sectional area.

As an instance of the latter class, take Gordon's formula :—

Let P = the total crippling load in tons.
„ f = the crippling stress on a short length, in tons per square inch.
„ A = cross-sectional area in square inches.
„ b = a constant, dependent upon the type of pillar, and to be found by experiment.
„ l = length of pillar in inches.
„ d = least width or least diameter in inches.

$$P = \frac{f A}{1 + b\left(\frac{l}{d}\right)^2} \quad \text{Equation XXXV.}$$

And the crippling load per square inch

$$\frac{P}{A} = \frac{f}{1 + b\left(\frac{l}{d}\right)^2} \quad \text{Equation XXXVI.}$$

For mild steel pillars built up of plates, channels, angles, etc., and with ends flat or fixed, f = 18 tons per square inch, and $b = \frac{1}{900}$.

Apply this formula to pillars A and B in Fig. 43. Both are practically equal in their least diameters and cross-sectional areas, and they are assumed to represent pillars of equal lengths.

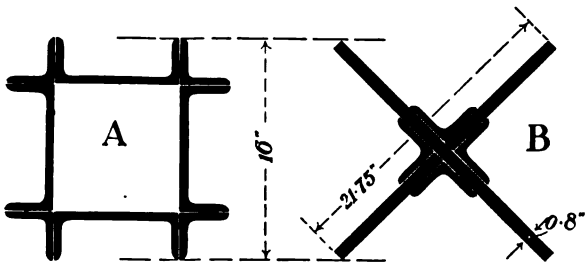

FIG. 43.

According to Gordon's formula as commonly used, these pillars should be equal in strength ; but an inspection of the sketches shows that the metal in A is disposed in a manner better fitted to resist bending or buckling than in the case of B. Using a mathematical paraphrase, we may say, that while the areas in both cases are equal, the radius of equivalence is greater in A than in B, since in A the material as a whole is further away from the neutral axis.

We see then, that since Gordon's formula does not take the disposition of the metal into account, there is always an element of uncertainty in results obtained by its aid. To cover this risk we must allow a higher factor of safety than would be otherwise necessary.

Conversely, in using formulæ involving the radius of equivalence, although we lose time we may save material, and in any case we obtain greater certitude, and consequently our factor of safety need not be so high.

It is not unusual for factors of safety for pillars to be selected at haphazard without any reference to the length or slenderness of the pillar. Four, five, and six seem to be favourite figures for quiescent loads ; but Mr. Shaler-Smith advocates a sliding factor of safety to allow for the imperfections of built-up pillars, which imperfections, of course, increase as the length increases.

Let F = factor of safety for steady loads.
„ l = length of pillar in inches.
„ d = least diameter in inches.
„ $m = \frac{l}{d}$

$$\text{then } F = 4 + \frac{m}{20}$$

$$= 4 + 0{\cdot}05\,\frac{l}{d}.$$

Another formula, used by Mr. Alexander Drew, C.E., gives somewhat higher results. In this

$$F = 4 + 0{\cdot}07\,\frac{l}{d}.$$

For a rolling load, such as an

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express train at full speed, the factor of safety should be twice as high as for a quiescent load. For a mixed load we must add the stationary or dead load to twice the rolling load to get the *equivalent* dead load. This simple rule is the same in effect as Rankine's more complex rule :—

"Given the proportions of steady and rolling loads on a structure, to find the factor of safety for the mixed load, multiply the factor of safety for a steady load by a number proportional to the steady part of the load, and the factor of safety for a rolling load by a number proportional to the rolling part of the load; add together the products, and divide by the sum of the multipliers." Let us now find the equivalent breaking load by both methods. Let dead load = 24 tons, while rolling load = 36 tons; let the factor of safety for steady load be 4, and for rolling load 8. The multipliers are therefore 2 and 3, and the answer is 384 tons.

It is easy to prove that the factor of safety for a load suddenly applied should be twice as high as for a very gradually applied load.

Let W tons = a weight suddenly hung on a vertical rod, but applied without shock.

x inches = the maximum elongation of the bar, produced by the pull of the weight W.

The work done on the bar

= force × distance

= W. x (inch-tons).

Let S tons be the total internal tensile stress at the instant of maximum elongation. On any given bar the stress is proportional to the extension or stretch. On the bar in question the stretch increases from zero to x. Therefore the stress increases from zero to S, and the mean stress will be $\frac{S}{2}$.

The energy stored in the bar by virtue of its elasticity

= average force × total distance,

$$= \frac{S}{2}x.$$

Now the work done on the bar equals the energy stored in the bar, therefore

$$Wx = \frac{S}{2}x;$$

$$\therefore \quad W = \frac{S}{2};$$

$$\therefore \quad 2W = S.$$

We see, then, that the total elastic stress in the bar at the moment of maximum elongation is equal to twice the load on the bar; whereas, if the load had been very gradually applied, the total load and the total stress would have been numerically equal. At the moment of maximum elongation the total load and the total stress are not in static equilibrium: the latter exceeds the former by W tons, acting in the upward direction. Therefore a series of vertical oscillations or vibrations are set up. The oscillations grow less and less till the bar comes to rest, with an extension of $\frac{x}{2}$ inches, and an internal stress numerically equal to the external load.

It should now be clear why we multiply the suddenly applied load by two, in order to obtain the equivalent dead load.

Few loads, however, come on to a structure with the speed of an express train, therefore to multiply the live load by $1\frac{1}{2}$ may sometimes prove an ample allowance for intermediate conditions.

A crowd of persons in a room constitute a live load, but they are not likely to sweep into the room like a flood. If rooms are to be used for dancing or drilling, it is extremely desirable to allow twice the weight of the crowd for the equivalent dead load; for although the floor cannot be crowded, yet the rhythmic swing of the floor, if perceptible, may prove very disconcerting.

This digression should have served two useful purposes. It should have shown what changes are usually made in the factor of safety for loads of different character, and it should also have suggested a better way, *i.e.*, finding an equivalent dead load instead of varying the safety factor.

Reverting to Gordon's pillar formula and Shaler-Smith's factor of safety formula, we shall now be able to effect a combination which can be worked out and tabulated once and for all, instead of working at the same formula year after year. Thus

$$\text{Working load} = \frac{\text{crippling load}}{\text{factor of safety}}$$

$$= \frac{Af \div \left[1 + b\left(\frac{l}{d}\right)^2\right]}{4 + \frac{1}{20}\frac{l}{d}}.$$

If we divide by A, we find the working load per square inch, *viz.*,

$$\frac{f \div \left[1 + b\left(\frac{l}{d}\right)^2\right]}{4 + \frac{1}{20}\frac{l}{d}}.$$

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This formula has been worked out and plotted in Fig. 44. We have now only to find the ratio $\frac{l}{d}$, and we know at a glance the safe working load in tons per square inch. This formula need not be used for values of $\frac{l}{d}$ less than 12, and lengths greater than 40 diameters are inadvisable.

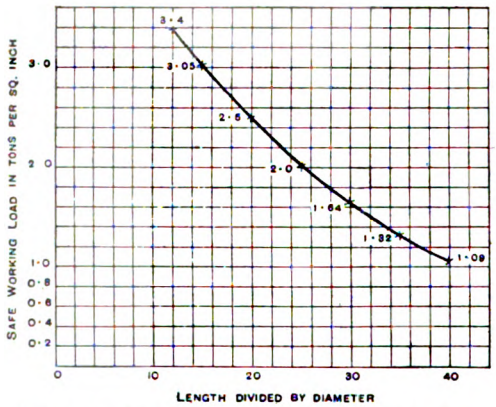

FIG. 44.—GRAPH OF GORDON'S FORMULA FOR BUILT-UP STEEL PILLARS, WITH ENDS FLAT OR FIXED.

We cannot apply Shaler-Smith's factor of safety formula to pillar formulæ involving the radius of equivalence (or gyration) in such a manner as to get out a diagram of *working* loads; because the ratio of least diameter to radius of equivalence is different for every dissimilar section. I have proposed the adoption of a sliding factor of safety which is dependent upon the radius of equivalence, *viz.*:—

$$F = 4 + \frac{K}{100},$$

where l = length and r = radius of equivalence, while $K = \frac{l}{r}$.

This rule is based on the fact that, in built-up pillars, r usually lies between $\frac{d}{4}$ and $\frac{d}{5}$. Using these ratios in Shaler-Smith's formula, we obtain $F = 4 + \frac{K}{80}$ and $F = 4 + \frac{K}{100}$. Now as there is much greater certainty about pillar formulæ involving r instead of least diameter, we can safely employ the smaller of these values, *viz.*:—

$$F = 4 + \frac{K}{100}.$$

We are thus able to draw up a table which will give us the working load per square inch for every value of $\frac{l}{r}$.

It is interesting to note that $\frac{18A}{1 + \frac{1}{900}\left(\frac{l}{d}\right)^2}$ (Equation XXXV.) is practically equal to $\frac{18A}{1 + \frac{1}{18,000}\left(\frac{l}{r}\right)^2}$ (Equation XXXIV.) when $d = 4 \cdot 5r$; note that $4 \cdot 5r$ is the mean between $4r$ and $5r$.

(*To be continued.*)

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ARRANGEMENT OF MACHINERY IN A MODERN COTTON MILL.

PART II.

By WM. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

IT is absolutely essential for the mill planner to have at his command all the information possible in respect to the production of every machine in a cotton mill. A mill plan cannot be made unless "productions" are known, so it is strongly urged on the reader to master this phase of the subject by making himself competent to calculate from given data what a machine will produce; this applies particularly to the drawing, roving, and spinning machines. The productions of such machines as the bale-breaker, opening machines, hopper feeder, and in some cases cards, may be committed to memory, partly because the range of variation is small, and also because some machines have a fixed production, and no variation is made in it, whatever the ultimate counts may be at the spinning machine.

PRODUCTIONS.

I shall, as far as possible, show how the productions of the various machines can be calculated, and explain the factors upon which such calculations are based.

Hopper Bale Breaker.—This is the first machine in a cotton mill through which the cotton passes. Its production is a fixed one. For Egyptian cotton this will reach 15,000 lbs. per hour, and for American cotton, as much as 40,000 lbs. per hour can be passed through. Less than this can be produced by simply running the whole machine at a slower speed.

Porcupine Opener.—Often used as a feeder in opening and cleaning the cotton before it enters the vertical or Crighton opener; production fixed, and equal to the opener to which it is attached by pipes; about 30,000 to 40,000 lbs. per week.

Hopper Feeder.—This is used to feed direct to the opener, or indirectly to one or more machines by the use of lattices. Its production depends on the machine or machines to which it is attached, but it can be worked so as to produce as much as 30,000 lbs. per week.

Vertical Opener or Crighton's Opener.—Single or double form of machine. Production 30,000 to 40,000 lbs. per week. If attached to one or a series of machines, the production will be equal to the last machine. For instance, an installation arranged by Platt Bros., of Oldham, has the following series of machines all connected:—Lattice feeder or porcupine opener, vertical or Crighton opener, delivering on to two single scutchers. The production of the vertical opener in this case is arranged for 28,000 lbs. per week.

Exhaust Opener (Horizontal).—Production up to 30,000 lbs. per week.

Large Size Opener.—Production 25,000 lbs. per week. This is the same for either the single or double form: the Hopper Feeder, if attached, has the same production.

Scutcher.—Production 12,000 to 20,000 lbs. per week, depending on the quality of work required. It is generally at this machine that the weight of a given length of the lap begins to be a factor requiring consideration. As a rule, the total weight of the lap is used; and very often each lap is weighed, to see if it comes up to a fixed standard that has been decided upon. In reality the weighing is based upon the weight of a certain length, which is usually two yards. The weight of this two yards is based upon the hank of lap required, and is reduced down to the weight of two yards for the sake of convenience; but of course any number of yards can be taken to test the hank. The hank of the lap suitable for any given counts of yarn is found by the following rule:—

$$\text{Hank of lap} = \frac{\text{Counts to be spun} \times \text{number of doublings}}{\text{Draft at each machine from card to spinning machine.}}$$

It will be seen from this rule that the hank of the lap may vary considerably, while yet the counts of yarn remain the same: the draft in the various machines can be regulated

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to compensate for heavier or lighter hank laps. To find the hank of a lap we must first weigh a given number of yards; this weight (in ounces) will enable us to find what length of lap in yards would weigh one pound. The length of lap thus found, if divided by 840 yards, will give the hank of the lap.

Exercise.—Two yards of lap weigh 13 ounces.

From this we find that the length of a pound of lap will be $(2 \times 16) \div 13$ and this divided by 840 will give $(2 \times 16) \div (13 \times 840) = 0{\cdot}00293$ hank lap. Two yards do not always weigh 13 ounces, and it may be convenient or necessary to use shorter or longer lengths on which to base the weighings. It is therefore usual to find constant numbers, or dividends, as they are called. This is done by leaving out the weight of two yards of lap in the above calculation, and working the sum so: $(2 \times 16) \div 840 = 0{\cdot}03809$. This number is called the *dividend*, and we use it to find the hank of the lap by dividing into it the weight, in ounces, of two yards.

Table I. gives a series of dividends for finding the hank lap; to use it we simply divide the dividend by the weight in ounces of the length of lap opposite the dividend in the table.

TABLE I.

Yards.	Dividend.	Yards.	Dividend.
1	0·019047	4	0·076188
2	0·038094	5	0·095235
3	0·057141	6	0·114282

The student is recommended to calculate these dividends for himself, so that he will know exactly how they have been obtained as well as how to use them.

The weight of lap per yard made by the scutcher does not vary much, and can easily be remembered.

	Per yard.
Indian cotton is usually	13½ oz.
American cotton is usually . . from	12 to 13½ oz.
Egyptian cotton is usually . . ,,	11 to 12 oz.
Egyptian (combed) cotton is usually ,,	10 to 11 oz.

Carding Engines.—Production varies as follows:—

		Per hour.
Indian cotton for counts . . .	10s to 20s . .	15 to 23 lbs.
American cotton for counts . .	20s to 40s . .	11 to 18 lbs.
Egyptian (carded) cotton for counts	40s to 60s . . .	5 to 7 lbs.
Egyptian (combed) cotton for counts	60s upwards . .	7 to 8 lbs.
Sea Islands cotton for counts . .	. . . . .	3 to 5½ lbs.

Here we find a wide variation in the production, so judgment must be brought to bear on the matter. It is always best to be on the safe side by having extra cards. Factors to be carefully considered are:—The character of the wire used—this is a highly important matter, as the quality and finish of the final sliver depends greatly upon it; the grade of cotton used, as well as the purpose for which the finished yarn is required. The following rule will enable the production to be readily found.

$$\text{Production in 10 hours} = \frac{\left\{\begin{matrix}\text{Minutes}\\ \text{in}\\ \text{10 hrs.}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Revs.}\\ \text{of}\\ \text{doffer.}\end{matrix}\right\} \times 24\tfrac{3}{4} \text{ in.} \times 3{\cdot}1416 \times \left\{\begin{matrix}\text{Weight of}\\ \text{sliver in}\\ \text{grains per}\\ \text{yard.}\end{matrix}\right\}}{36 \times 7000.}$$

No student ought to be satisfied with such a rule as given above, and he certainly ought not to commit it to memory. The rule is simply a convenient method of stating clearly a process of reasoning. The doffer is the deciding factor for the speed, and the weight of the sliver or the cotton on the doffer fixes the quantity. If the weight per yard is multiplied by the length delivered in a given time we get the production.

In reality we ought to find the weight of the sliver in pounds; but we have no means of weighing decimals of a pound directly, so we have created another method by adopting 7000 grains in one pound. The weight of a yard of sliver in grains divided by 7000 will give us the fraction of a pound the yard of sliver weighs. This accounts for the figure 7000 in the denominator.

The length in inches of sliver delivered is found by determining the circumference of the doffer; this is done by multiplying the diameter (24¾ inches) by π or 3·1416; if this is divided by 36 (the number of inches in a yard) we obtain the yards delivered in one revolution. When we know this, we simply multiply it by the number of revolutions of the doffer in 10 hours, and so obtain the production per day.

The important factors for the student to know, when he understands how to calculate the production, are the most suitable speeds for the doffer, and the weight of the card sliver which experience suggests as the best for the ultimate yarn to be spun. This is clearly not a question that can be deduced or calculated from any given data: experience and judgment are required, so it is necessary to give particulars that will help in deciding the question. Table II. is given as a basis;

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but, as already remarked, students must always be on the alert to gather all such information for themselves, as it may be considered the principal source of value to any man who occupies, or desires to occupy, a responsible position in a cotton mill.

The number of nips per minute may be as high as 95 for medium qualities on Egyptian cotton, so this would give a proportionate increase in the production.

TABLE II.—PRODUCTION OF THE CARD.

Counts.	Kind of Cotton.	Weight of Lap per yard from Scutcher.	Hank Carding.	Weight of Sliver in grains per yard.	Revs. of Doffer.	Lbs. per Card in 10 hours.	Usual Draft.
16	Indian or American . .	13½ oz.	0·138	60 grains.	18	200 lbs.	92
18	Indian or American . .	13½ ,,	0·138	60 ,,	16	177 ,,	92
20	Indian or American . .	13½ ,,	0·138	60 ,,	15	166 ,,	92
30	American	13 ,,	0·154	54 ,,	15½	154 ,,	99
40	American	12 ,,	0·173	48 ,,	13¼	117 ,,	103
40	Egyptian	12 ,,	0·189	44 ,,	10	81 ,,	111
50	Egyptian	11½ ,,	0·208	40 ,,	10	74 ,,	118
60	Egyptian	11 ,,	0·208	40 ,,	10	74 ,,	112
70	Egyptian	11 ,,	0·231	36 ,,	10	66 ,,	125
80	Egyptian	11 ,,	0·231	36 ,,	10	66 ,,	125
80	Egyptian (combed). . .	11 ,,	0·231	36 ,,	10	66 ,,	125
90	Egyptian (combed). . .	10 ,,	0·277	30 ,,	9	50 ,,	136
100	Egyptian (combed). . .	10 ,,	0·277	30 ,,	8	44 ,,	136

The draft, it will be noted, allows for about 5 per cent. being lost as waste. If 13½ oz. = 1,508 grains goes into the card, and a 60-grain sliver is delivered, the draft would be 97 : but as 5 per cent. waste is made, we must set the card to allow for this loss.

Sliver Lap Machine.—This machine unites the slivers from the carding engine, or from the first passage of drawing frames, into a lap for the comber or ribbon lap machine. Its production is from 450 to 500 lbs. per day, and one machine will serve about six combers.

Ribbon Lap Machine, or draw frame and lap machine combined. This machine combines the first passage of draw frames and the sliver lap machine, thus dispensing with the first-mentioned machines. Production 450 to 500 lbs. per day.

Combing Machines.—The production varies according to speed (generally expressed as so many nips per minute), as well as quality of work done (generally indicated by the amount of waste taken out). Table III. gives the production.

Table III. could be extended by simple proportion, and students are advised to do this as an exercise, so as to obtain a complete list for all probable conditions. If one actual production is known, and the nips, waste, width of lap, and weight of lap are also remembered, it will be an easy matter to calculate the production for any other set of conditions. The weight of lap for Sea Island cotton is usually from 9 to 10 dwts. per yard, and the waste 22 per cent. The weight of lap for Egyptian cotton has a greater range, usually from 9 to 12 dwts. per yard, whilst the waste is about 18 per cent.

TABLE III.—PRODUCTION OF COMBING MACHINES.

No. of Nips per minute.	Weight of Lap per yard. Dwts.	Width of Lap. Inches.	Waste per cent.	Lbs. per head of Combed Sliver per hour.	Kind of Cotton.
			SINGLE NIP COMBER.		
80	8	7½	20	6·37	Sea Islands.
80	9	8½	20	7·22	
80	11	10½	20	8·92	
80	9	7½	18	7·5	Egyptian or American.
80	10½	8½	18	9·0	
80	13	10½	18	11·15	
			DOUBLE NIP COMBER.		
120	8	7½	20	9·23	Sea Islands.
120	9	8½	20	10·47	
120	11	10½	20	12·93	
120	9	7½	18	10·88	Egyptian or American.
120	10½	8½	18	13·04	
120	13	10½	18	16·12	

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American cotton has a lap similar in weight to Egyptian; but less waste is taken out, being about 16 per cent.

Drawing Frame.—The production of this machine in ten hours can be found by the following rule :—

$$\frac{\left.\begin{matrix}\text{Revs. of}\\ \text{front}\\ \text{roller}\\ \text{per min.}\end{matrix}\right\} \times 60 \text{ min.} \times 10 \text{ hrs.} \times \left\{\begin{matrix}\text{Circum.}\\ \text{of}\\ \text{front}\\ \text{roller}\end{matrix}\right\}}{840 \text{ yards} \times 36 \text{ inches.}} = \left\{\begin{matrix}\text{Hanks}\\ \text{per de-}\\ \text{livery.}\end{matrix}\right.$$

This rule simply gives us the length of the sliver turned through the front roller, divided by 840 to give hanks. To find the weight in pounds we must divide the hanks by the hank of the sliver. It must be noted that this production is calculated; in a day's work the actual production will be less than this, due to waste, stoppages, etc., and as this loss of time is considerable, it must be taken into account. Some people allow as much as 4 per cent. per delivery in each head, so that in a drawing frame of seven deliveries per head the loss would be 28 per cent. on the calculated production.

A table of productions similar to Table IV. ought to be drawn up by the student and kept in his note-book.

Table IV. is merely a specimen of how to tabulate results that are calculated, but in addition to this, careful notes of actual results ought to be jotted down, as these will be more valuable. Table V. meets these requirements, and gives other useful data.

TABLE IV.

Revolutions of Front Roller 1⅜ in. diameter.	Decimal Hank Sliver.	Production in Hanks and Lbs. per delivery per hour from											
		3 deliveries loss 12 %		4 deliveries loss 15·3 %		5 deliveries loss 18·5 %		6 deliveries loss 21·6 %		7 deliveries loss 25 %		8 deliveries loss 32 %	
		hks.	lbs.	hks.	lbs.	hks.	lbs.	hks.	lbs.	hks.	lbs.	hks.	lbs.
300	0·15	2·26	15·0	2·19	14·6	2·10	14·0	2·02	13·4	1·93	12·8	1·82	12·1
320	0·15	2·43	16·2	2·33	15·5	2·24	14·9	2·15	14·3	2·06	13·7	1·96	13·0
335	0·15	2·53	16·8	2·44	16·2	2·34	15·6	2·26	15·0	2·16	14·4	2·06	13·7
350	0·15	2·64	17·6	2·54	16·0	2·36	15·7	2·35	15·6	2·25	15·0	2·14	14·2
360	0·15	2·70	18·0	2·61	17·4	2·34	15·6	2·42	16·1	2·31	15·4	2·21	14·7

It will be noticed that about 18·5 per cent. is allowed for stoppages.

Fly Frames.—The production of a fly frame can be calculated readily from the front roller and a due allowance made for stoppages, but this varies considerably, so care must be taken in settling the percentage of loss. Table VI. gives calculated results based on actual factors, and with due allowance for stoppages :—

TABLE V.—PRODUCTION OF DRAW FRAME.

Diameter of Front Roller.	Hours run out of 56½ hours.	Revolutions of Front Roller per minute.	Weight of Sliver per yard in grains.	Hank of Sliver.	Lbs. delivered in 10 hours.	Kind of Cotton and Counts spun.
1⅛ in.	46	400	66	·126	180·5	10s to 20s China or Indian cotton.
1⅛ ,,	46	400	60	·138	164·2	
1¼ ,,	46	350	60	·138	158·7	20s to 24s American.
1¼ ,,	46	350	54	·154	142·8	24s to 32s American.
1¼ ,,	46	350	48	·173	126·9	32s to 40s American.
1⅜ ,,	46	300	48	·173	120·1	32s to 40s American or Low Egyptian.
1⅜ ,,	46	300	44	·189	110·2	
1⅜ ,,	46	300	40	·208	100·0	
1½ ,,	46	280	48	·173	122·4	30s to 40s Egyptian.
1½ ,,	46	280	44	·189	112·2	40s to 45s Egyptian.
1½ ,,	46	280	40	·208	102·1	45s to 50s Egyptian.
1½ ,,	46	250	40	·208	91·1	60s Egyptian.
1½ ,,	46	250	36	·231	81·9	70s Egyptian.
1½ ,,	46	200	40	·208	72·7	80s Egyptian.
1½ ,,	46	200	36	·231	65·5	90s Egyptian.
1½ ,,	46	200	30	·277	54·5	100s Egyptian.

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TABLE VI.—PRODUCTIONS OF FLY FRAMES.

Hank Roving.	Revolutions of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle in 10 hours.	Lbs. per Spindle in 10 hours.	Percentage of time lost in doffing, etc.
Slubbing Frame.—Indian and Low American Cotton. Diameter of front roller, 1⅛ in. Speed of spindle, 550 revolutions per minute.						
0·5	169	3·24	0·919	9·165	18·33	22·8
0·625	151	3·63	1·027	8·787	14·06	16·0
0·75	138	3·97	1·125	8·35	11·13	13·6
0·8	134	4·1	1·162	8·2	10·25	12·7
Slubbing Frame.—American Cotton. Diameter of front roller, 1⅛ in. Speed of spindle, 550 revolutions per minute.						
0·625	177	3·10	0·79	10·66	17·06	22·7
0·75	161	3·40	0·866	10·29	13·72	17·9
0·875	150	3·67	0·935	9·9	11·32	15·2
1·0	140	3·92	1·000	9·52	9·52	12·6
1·125	131	4·18	1·066	9·11	8·1	10·6
1·25	125	4·39	1·118	8·84	7·07	9·1
1·5	114	4·80	1·224	8·27	5·51	6·8
Slubbing Frame.—Good Egyptian and Sea Islands Cotton. Diameter of front roller, 1⅛ in. Speed of spindle, 400 revolutions per minute.						
0·75	150	2·61	0·606	10·47	13·96	19·6
0·875	141	2·82	0·654	10·12	11·56	16·5
1·0	132	3·02	0·700	9·75	9·75	14·0
1·125	124	3·22	0·746	9·36	8·32	12·0
1·25	118	3·37	0·782	9·08	7·27	10·7
1·375	113	3·54	0·820	8·77	6·38	9·5
1·5	108	3·7	0·857	8·47	5·65	8·1
2·0	93	4·27	0·989	7·6	3·8	5·7

(To be continued.)

THE MECHANICS OF THE PRESSER.

By R. ROYDS, B.Sc.

PREVIOUS to the introduction of the presser, the bobbins formed on bobbin and fly frames were soft and spongy, and contained a very limited length of roving compared with the size of the bobbin. The function of the presser is to allow a firm and compact bobbin to be built, which can be easily handled without causing unnecessary waste. The length of roving which such a bobbin contains is much greater than the length which the same size of bobbin contained before the presser was employed. This means a saving in time and labour both on these frames and on the spinning machines, thereby reducing the cost of production in a proportionate degree.

It is proposed to examine the action of the presser from first principles. As its name implies, it exerts a pressure during the building of the bobbin, acting near the point at which the roving is passing on to the bobbin. The presser itself is supported on the hollow flyer leg C (Figs. 1 and 2) in such a manner that it is able to swivel round the leg. One part consists of a horizontal arm (B), flattened out towards the end (E), where it bears against the bobbin; the second part is situated on the other side of the hollow flyer leg, and is simply a vertical rod (A) parallel to the flyer leg, by which the whole presser is supported. The roving passes down the hollow flyer leg and is wrapped a few times round the presser arm, and then passes through the presser eye on to the bobbin.

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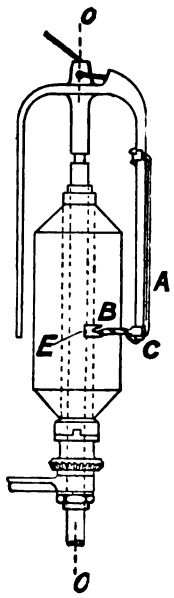

FIG. 1.—PRESSER APPLIED TO BOBBIN.

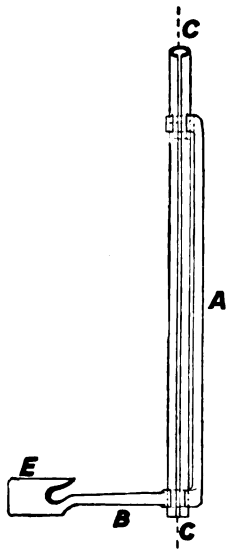

FIG. 2.—ENLARGED VIEW OF PRESSER.

When a body revolves about a centre an effect is produced upon it as if a force acted directly from the axis of rotation through the centre of gravity of the body; this force is generally known as a "centrifugal force." Let A and B (Fig. 3) be the centres of gravity of two parts of a body which is compelled to rotate round O, and let G be the centre of gravity of the whole body. Forces can be considered to act upon A and B in the directions O A and O B respectively, and these will together be equivalent to a single force acting in the direction O G. Now suppose the body is centred at C, which centre is compelled to rotate about the centre O, and thus carry the body round O.

Let m_1 = mass of part of the body with centre of gravity at A.

Let m_2 = mass of part of the body with centre of gravity at B.

Let ω = angular velocity of C about O, measured in radians per second.

If m_1 and m_2 are the masses in lbs., and if all distances are measured in feet, the centrifugal forces are $m_1\omega^2OA/g$ lbs., $m_2\omega^2OB/g$ lbs., and $(m_1 + m_2)\omega^2OG/g$ lbs., in the directions OA, OB, and OG respectively, g being the acceleration due to gravity, *viz.*, 32·2 ft. per second per second. Draw perpendiculars CK, CM, and CL from C upon OA, OB, and OG respectively, and take moments about C. Then

$$\frac{m_1\omega^2OA.CK}{g} - \frac{m_2\omega^2OB.CM}{g} = \frac{(m_1 + m_2)\omega^2OG.CL}{g}.$$

If $m_1\omega^2OA.CK$ is greater than $m_2\omega^2OB.CM$ the point B will tend to move nearer the centre O. In this case the moment

$$(m_1 + m_2)\omega^2OG.CL/g$$

must act so as to cause B to tend to move inwards. Thus G and B must of necessity lie on opposite sides of the line OC; that is, G and A will be on the same side of OC. To maintain the body stationary relative to the centre C would require some additional force. If this force acts outwards from the centre O, its line of action must be on the same side of OC as B.

Now consider the presser represented in plan in Fig. 4. Let A be the centre of gravity of the vertical leg and B the centre of gravity of the horizontal arm. The points O and C represent the centres of the spindle and the hollow flyer leg respectively. E is the point of contact of the presser and the bobbin; the straight line EH is the flattened part of the presser arm, and the direction of

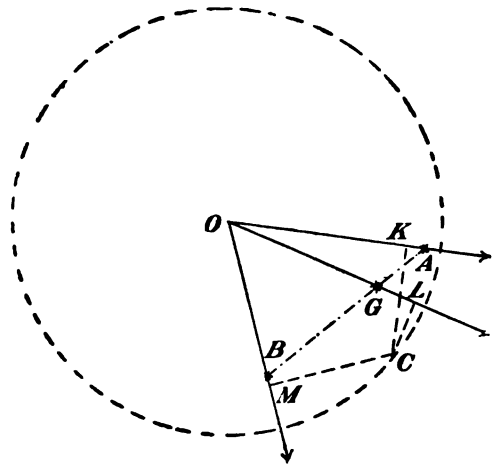

FIG. 3.—TO ILLUSTRATE MECHANICAL FORCES ACTING ON PRESSER.

this line is such that the point of contact E varies but little in its position relative to the presser as the bobbin builds. Let P be the pressure between presser and bobbin, its line of action being OE, perpendicular to EH. Draw CD perpendicular to OE. P × CD will be the moment of the force P about C, which balances the moment of the force acting along OG. If m_1 and m_2 are the masses in lbs. of the vertical leg and the presser arm respectively, G, the centre of

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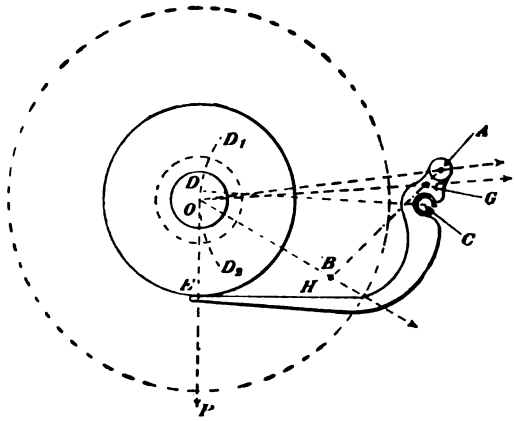

FIG. 4.

gravity of the whole presser, must lie on the same side of OC as the vertical leg. Let CL (a line not drawn in Fig. 4) represent the perpendicular distances of C from OG (compare Fig. 3). Then

$$P.CD = \frac{(m_1 + m_2)\omega^2 . OG.CL}{g}$$

$$P = \frac{(m_1 + m_2)}{g} \omega^2 \frac{OG.CL}{CD} \text{ lbs.}$$

$$= \frac{m\omega^2}{g} . \frac{OG.CL}{CD} \text{ lbs.}$$

Since $m\omega^2/g$ is a constant, the pressure P will be proportional to OG.CL/CD.

It is often asserted that the pressure exerted upon the bobbin by the presser diminishes as the diameter increases. P can only decrease or increase as OG. CL/CD diminishes or increases. As the diameter of the bobbin increases OG will decrease slightly, but this of itself could only cause a very slight change in P. The locus of D is a curve through O, commencing at a point D_1 (for the empty bobbin) and finishing at a point D_2 (for the full bobbin). Thus C D increases gradually until D corresponds with O, and then decreases as D passes from O to D_2. The variation of C D will of itself cause a slight diminution in the pressure P until D gets to O, and an increase in P from O to D_2. If the parts of the presser are so arranged that the middle point of the arc in which G moves is the point of contact of a tangent to this arc drawn from O, C L will remain practically constant. It is therefore possible to maintain an approximately constant pressure upon the bobbin; it will probably diminish slightly until the bobbin gets about half full, because O G decreases slightly and C D increases slightly; after which it may remain constant during a certain increase in the diameter of the bobbin, as both O G and C D are then decreasing, whilst towards the latter part of the building of the bobbin, P will probably increase slightly, due to the rate at which C D decreases compared to the rate of decrease of O G.

Although P may be kept practically constant, the pressure per square inch of contact between presser and bobbin will decrease, because the bobbin is increasing in diameter and is getting softer. Theoretically, the bobbin and the presser could only touch along a single line, which would be parallel to the spindle. The larger the bobbin the less does the curvature of the surface become, and in conjunction with the more spongy condition allows the presser to touch over an area which increases as the diameter increases. It would, perhaps, be an advantage if the point G was so arranged that C L increased gradually during building, to such a degree as to compensate somewhat for the increase in the area of contact. This would be likely to give a better distribution of the pressure per square inch between the presser and the bobbin.

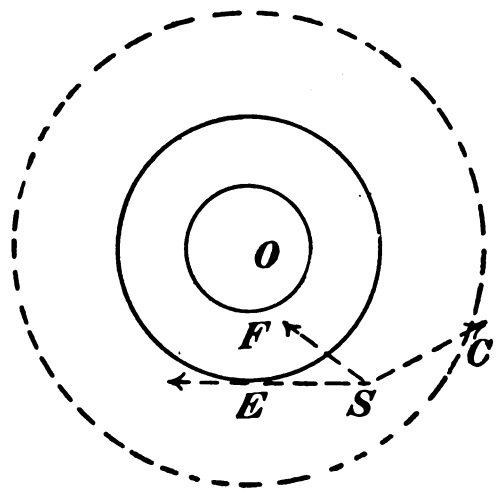

FIG. 5.

The tension in the roving as it is being wound upon the bobbin will cause an additional pressure. The frictional resistance between the roving and the presser arm may also slightly modify the pressure. In Fig. 5, suppose CS and SE are the directions which the roving makes when passing on to the presser arm from the flyer leg and when passing on to the bobbin respectively. The tensions in the roving at C and E will act on the presser

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as forces in the directions shown, *viz.*, S C and S E. These two forces can be compounded into some single force S F, which will have a moment about C. This action will be a constant factor all through the building of the bobbins and increases the pressure. The tension in the roving at E will be much greater than the tension at C, owing to the wrapping of the roving round the presser arm.

The Balancing of the Flyer.

It would be easy to ensure perfect balance of the spindle and flyer, if the point G was stationary; but since it must of necessity alter its position relative to O, perfect balance cannot be obtained except for some one position of the presser. The maker usually adjusts the balance when the presser is in the position which it has when the bobbin is half-full, that is, when the bobbin is of such a diameter that the difference between it and the diameter of the empty bobbin is one-half the difference in diameter between the full and empty bobbins. In this case the hollow flyer leg will act as if it were slightly too heavy when the bobbin is less than half-full, and slightly too light when the bobbin is more than half-full. This necessarily follows, because the centre of gravity, G, moves towards the centre O, as the presser arm moves outwards.

A NOVEL APPARATUS FOR RÖNTGEN RAY EXAMINATIONS.

By ALFRED GRADENWITZ, Ph.D.

AN interesting method of utilising Röntgen rays in medicine is exemplified by the *orthodiagraph*, recently brought out by the Allgemeine Elektricitäts Gesellschaft, Berlin. As Röntgen rays are given off from a very small spot on the cathode of the vacuum tube, and radiate in all directions, the image of any object projected on the luminous screen or photographic plate will be a silhouette, the outline of which coincides with the points where the Röntgen rays which just graze the body cut the screen. Accordingly, the image of the object will be more or less magnified. It is impossible with an ordinary Röntgen apparatus to ascertain the true size of an organ of the human body, unless by troublesome calculations which are not always trustworthy. Finally, considerable distortion of the image is produced.

If, on the other hand, the Röntgen rays throwing the shadow of the body on a screen could be rendered parallel, striking the screen at right angles, a record of the object in its true shape and size would be obtained. Similar results are realised by using the apparatus illustrated in Fig. 1. A particularly valuable feature of the apparatus is that the record is readily obtained, not only in a horizontal, but in any desired position of the drawing frame.

The person experimented on is placed between a system of levers, constituting a rigid connection between the Röntgen bulb and a drawing stylus fixed in the middle of the luminous screen. The Röntgen bulb is adjusted so as to lie in the prolongation of the drawing stylus, so that the central rays issuing from the bulb will strike the luminous screen just at the foot of the stylus. Movements in any desired directions are effected by the system rotating round two axes, parallel to each other, namely, round a pointed bearing and the axis of a cone. The drawing frame is placed below the luminous screen, being parallel to the latter, and at about 1 cm. distance from it. The frame is fitted with a sheet of pasteboard, whereon the records are made by the drawing stylus. The luminous screen moves over the pasteboard, while the Röntgen bulb, following any movement of the luminous screen and drawing stylus, and always remaining in the latter's prolongation, will permanently send its central rays through the foot of the drawing stylus. By drawing the latter along the outline of the organ in question, as formed on the movable luminous screen, the exact shape and size of the organ may be recorded. The drawing plane may be given any desired position, according as

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the person to be examined is either standing or lying. Drawing may also be effected immediately on the body, in which case the pasteboard is removed from the drawing plane, and a special "dermatograph" stylus used instead of a pencil. There are additional means for accurately marking the position of the body, and by thus modifying the usual method of operation, so as to use only central rays, the position of any foreign object contained in the body may be ascertained.

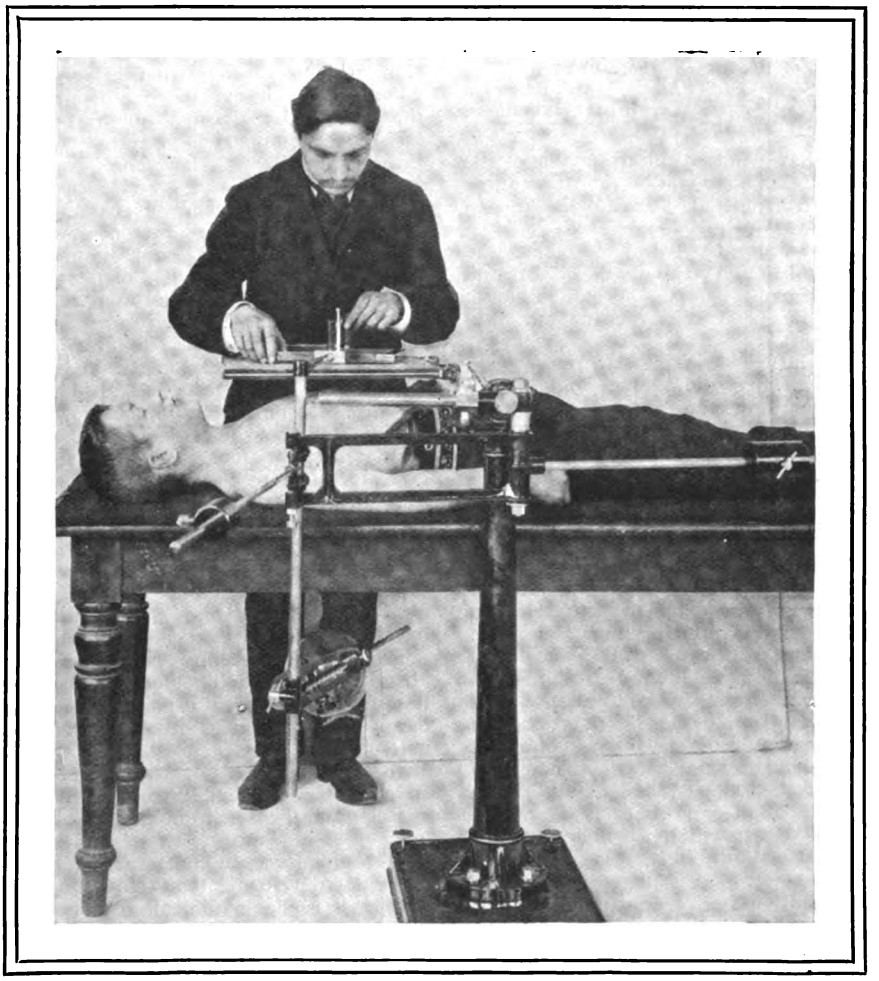

FIG. 1.—THE ORTHODIAGRAPH IN USE.

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REVIEWS.

The Theory of Heat. By Thos. Preston, M.A., D.Sc., F.R.S. Second edition, revised by **J. Rogerson Cotter, M.A.** pp. xx + 838, with 234 illustrations. (London: Macmillan & Co., 1904.) Price 18s. net.

Ten years have elapsed since the issue of the first edition of this book, and in that time many important advances have been made in the theory of Heat. Messrs. Macmillan & Co. have adopted the praiseworthy policy of keeping the books they publish well up to date; Dr. Preston died before he had prepared a second edition of his work, so the task of its revision has been entrusted to Mr. J. Rogerson Cotter, who has interfered as little as possible with the original subject-matter, while adding such information as is required in order to give a comprehensive account of the present stage of our knowledge of Heat. In accordance with the original plan of the author, no account is given of the application of thermo-dynamics to the theory of solutions; this course is justified by the fact that there are many excellent treatises on Physical Chemistry, in which a more extensive treatment is given than would be possible in a volume such as that at present under consideration. A certain amount of rearrangement has been found necessary; for instance, the section on the Dynamical Equivalent of Heat has been transferred from Chapter VIII. to Chapter IV., in order to bring it into close connection with the articles treating of the specific heat of water. A short account has been added of Reynolds' and Moorby's experiments, and an ingenious method due to Baille and Féry is described. In this latter a copper cylinder is balanced on a vertical axis in a rotating magnetic field. The cylinder tends to turn, according to Lenz's law, but is held stationary by a torque which is accurately measured. Since a quickly rotating magnetic field can be easily produced by the aid of polyphase electric currents, a considerable turning moment can be produced; the product of this into the angular velocity of the magnetic field gives the energy dissipated. The heat produced is determined by surrounding the cylinder with water, the rise of temperature of which is measured. This arrangement has all the advantages of the electrical methods of measuring J, while, being unaffected by any possible error in the magnitudes of the electrical units, the most important disadvantage of other allied methods is avoided. Details of the latest methods of liquefying refractory gases, such as hydrogen, are given on pp. 374–378. The principles underlying these methods are described later in the book, and this departure from a logical progression is scarcely to be commended; it may be urged, however, that the work under consideration is not intended for students commencing the study of Heat, but rather for those who have already obtained a general knowledge of the subject, and to these the arrangement should present no particular difficulty. The following sentence, which occurs on p. 480, would bear some improvement in construction: "The method of plotting the unrealisable, or James Thomson part of the isothermal curve has been described by Professor Ramsay and Young." The awkwardness, of course, arises from the unexpected use of the name "James Thomson" as an adjective. It is a pity that more alteration has not been made in the section devoted to diathermancy. This section of twenty-four pages is occupied almost exclusively in discussing the experiments of Tyndal, Magnus, and others of the same era, the results obtained being of little practical importance, and more likely to confuse than to assist the student. In three lines at the end of the section it is pointed out that "it is now fully established that pure air is highly diathermanous, but that the aqueous vapour and carbon dioxide present in ordinary air possess a well-marked absorbing power." The book would have been improved if the recent experiments establishing these facts were given, in which case a short note on the work of Tyndall and Magnus would have sufficed. Two important and interesting chapters have been added on the "Distribution of Energy in the Spectrum" and the "Measurement of Temperature by Radiation"; these should prove very useful, as they mark most important developments in the theory of Heat. Finally, it would be difficult to overpraise this book; it must suffice to state that the additions made are excellent, and the work as a whole deserves to retain the popularity which it has enjoyed for the last ten years.

Electricity in the Service of Man: A Popular and Practical Treatise on the Application of Electricity in Modern Life. By R. Mullineux Walmsley, D.Sc., F.R.S.E. pp. viii + 1208, with frontispiece, 5 plates, and 1208 illustrations. (London: Cassell & Co., 1904.) Price 10s. 6d. net.

This book comprises two parts: in the first, the history and principles of the science of electricity and magnetism are discussed; the second part is devoted to technical application of electricity. The reader of the first part will obtain a very clear grasp of the fundamental principles and laws upon which the remarkable

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developments of the last thirty years have been based; and with these as a guide, he will be able to follow the applications of electricity to the service of man, described in the second part. Taken as a whole, the book is not of the kind generally known as "popular." although it should be very popular with those who wish for accurate and lucid information on the subjects treated of. Mathematical methods are seldom employed, but the knowledge conveyed is of an exceptionally accurate character. The student commencing the study of electricity and magnetism could scarcely do better than read through the first part of this volume, in order to gain clear and connected ideas on the subject; he would then be in a position to follow a work in which greater attention is devoted to calculations. The descriptions of the machines in the second part are lucid, and the illustrations throughout the book are of the best possible character. Altogether, the book is one of the cheapest we know of, taking into account the trouble and expense which must have been incurred in producing it. A good index has been added.

Starters and Regulators for Electric Motors and Generators: Theory, Construction, and Connection. By Rudolf Krause, translated by C. Kinzbrunner, A.M.I.E.E., and N. West, A.I.E.E. pp. 132, with 97 illustrations. (London and New York: Harper & Brothers, 1904.) Price 4s. 6d. net.

The starting resistance is required to discharge so simple a duty that comparatively little attention has been devoted to its design in the past. Nevertheless, it is easily seen that this neglect is foolish in the extreme, for a badly designed starter will often cost as much as, or more than, one that is well designed; and the life of a motor will depend to a large extent on the design of the starter used with it. The book at present under consideration embodies the results of recent practice on the Continent, and is sure to be useful to students of electrical engineering; it is the only book on the subject at present on the market, and indeed, even the papers published in the technical press and in transactions of engineering societies may be counted on one's fingers. The first chapter is devoted to the conduction of electric currents, and contains much information of practical importance. The second chapter is devoted to circuit breakers and their design. The theory of starters is discussed in Chapter III.; this part of the subject is treated mathematically, but curves are freely used. The fifth chapter, devoted to the mechanical construction of starters, is the longest in the book; full details are given of starters for series and shunt motors, three-phase motors, and single-phase motors; the chapter ends with a description of automatic starting appliances. Chapter V. is devoted to the calculation of regulating resistances for generators and motors; the connections and construction of regulators are dealt with in the sixth and concluding chapter. A short index is added at the end of the book.

Classified Guide to Technical and Commercial Books; A Subject List of the principal British and American Works in Print. Compiled by Edgar Greenwood. pp. xii + 216. (London: Scott Greenwood & Co., 1904.) Price 7s. 6d. net.

A book which could be consulted for all existing works on any technical subject would be of the greatest usefulness, even although every week brings out a host of new books which should be known, and therefore a classified list would soon get out of date. The book before us contains a great amount of useful information, but the selection is somewhat puzzling. Thus, under the heading of "Heat," we find mention of W. R. Wallace Stewart's "Text Book of Heat," while Preston's Classical Treatise is not mentioned. Under the heading of "Physics," eleven books only are mentioned; no mention is made of the valuable treatise by Thomson and Poynting, of which two parts, on general physics and sound, have already been produced. The general usefulness of the book could only be gauged by consulting it according to one's needs: the number of references proves that in many cases useful information would be obtained, but the instances quoted above tend to suggest that, in some cases at least, greater completeness should have been aimed at.

Elementary Plane Geometry. By V. M. Turnbull. pp. 136. (London: Blackie & Son, 1904.) Price 2s.

This book is intended as an introduction to Descriptive Geometry, to be taken up after a course of experimental work involving measurement and numerical calculation. It is divided into four portions:—Section I. deals with angles at a point, parallels, and the elementary properties of triangles and quadrilaterals. Section II. deals with angle, chord, and tangent properties of circles. Section III. deals with the areas of triangles and quadrilaterals. Section IV. deals with ratio and proportion, and similar figures. Considerable care, and no small amount of originality, have been devoted to the writing of this book.

Carpentry Workshop Practice. By Charles F. Mitchell and George H. Mitchell. New and enlarged edition. pp. 112. (London: Cassell & Co., Ltd., 1904.) Price 1s. 6d.

The Beginner's Guide to Carpentry: A Practical Handbook for Amateurs and Apprentices. By Henry Jarvis. pp. 128. (London: Percival Marshall & Co., 1904.) Price 1s. net.

The scope of these books is sufficiently well indicated by their titles; both are clearly written, well printed, and amply illustrated. The book of Messrs. C. F. and G. A. Mitchell is suitable for artisans, and is illustrated with good line diagrams. Mr. Jarvis's book is mostly illustrated from photographs, showing the way to adjust and use carpenters' tools. Both books will doubtless be welcomed, each by the particular class for whom it was written.

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ANSWERS TO QUERIES

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the* 10*th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

OXIDISING.—Required, a chemical process for oxidising large articles of iron and steel.

The "Bower-Barff" process is the one usually adopted, and at present seems to be the most effective. The process consists in heating the iron or steel article to redness, and then subjecting it to the action of steam. Ferroso-ferric oxide is thus formed according to the equation

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

Iron and steel plates can be effectually covered with the black oxide by annealing them in closed vessels while the oxides due to the rolling (*i.e.*, FeO and Fe_2O_3) are still on them.

ORGANIC CHEMISTRY.—The hydrochloride of an organic base forms a crystalline salt with platinic chloride, which loses 4·86 per cent. of water when heated to 100° C. It contains 27·85 per cent. of chlorine, and 25·65 per cent. of platinum; but, if heated to 150° C., it contains 26·66 per cent. of platinum. Calculate the probable molecular weight of the base, the percentage of nitrogen it contains, and the number of atoms of nitrogen in the molecule.

N = 14, Pt = 194·9, Cl = 35·45, O = 16.

—*Theoretical Organic Chemistry Honours, Part I. S. and A. Dept.*, 1899.

First calculate the relative numbers of atoms of chlorine and platinum in the usual way.

No. of atoms of chlorine : No. of atoms of platinum

$$= \frac{27\cdot85}{35\cdot45} : \frac{25\cdot65}{194\cdot9} = 0\cdot786 : 0\cdot132 = 6 : 1 \text{ nearly},$$

hence the compound is evidently a hydrated salt of the normal type derived from the acid H_2PtCl_6.

To find the number of molecules of water, divide 4·86 by the molecular weight of water; the product $\left[= \frac{4\cdot86}{18}\right]$ is 0·27, practically double 0·132, which we have already taken to represent one atom. If, as is almost certainly the case, there is only one atom of platinum, there are two molecules of water.

If, then, the base is univalent, we may represent the salt by the formula $B_2'H_2PtCl_6.2H_2O$; if divalent, the formula is $B_1''H_2PtCl_6.2H_2O$.

Now the percentage of platinum, 25·65, corresponds with an atomic weight of 104·9, so that 100 corresponds with the molecular weight of the salt. The value of the latter is therefore

$$\frac{100}{25\cdot65} \times 194\cdot9 = 759\cdot8.$$

To obtain the sum of the atomic weight corresponding with B_2' or B_1'', subtract from 759·8 the sum of the atomic weights corresponding to $H_2PtCl_6.2H_2O$ or 445·6; the difference, 314·2, is the molecular weight of the base, if it is a divalent one; but if, as is more probable, it is univalent, the molecular weight is one-half of this, namely, 157·1.

Now assuming that the valency of the base is identical with the number of atoms of nitrogen contained in the molecule, *i.e.*, in the first instance 2, and in the second only 1, the percentage of nitrogen in the free base is evidently

$$\frac{14 \times 100}{157\cdot1} \left(= \frac{2 \times 14 \times 100}{314\cdot2} \right) = 8\cdot91.$$

PRESERVATIVE WASHES.—I have been washing some woodwork with carbolinium and some brickwork with calcarium. Could you tell me what these substances consist of, and how each may be prepared?

The two names "Calcarium" and "Carbolinium" are trade names, and give no aid to the identification of the substances they denote. Their constitutions, however, are probably somewhat like the following:—

A wash for woodwork is a mixture of phenol (one to two per cent.) and a compound formed by dissolving copper turnings in purified petroleum acid at ordinary temperatures. (The temperature must be kept low, otherwise the formation of this compound is retarded.)

Iron, zinc, or aluminium salts may be used, but they do not give results quite as satisfactory as the copper salt. These salts are prepared by decomposing the sodium salt of the petroleum acid (*i.e.*, soap) by the sulphate of the metal, the product being then dissolved in "ligroin" (*i.e.*, the distillate between 40° and 150° of the crude American petroleum).

A wash for brick and stonework consists of a mixture of precipitated chalk and alcohol in the proportions of two ounces of the former to a pint of the latter. This has the effect of filling up all the interstices, and also hardening the material.

CENTRIFUGAL FORCE. — Explain on general principles, without calculation, why the tension of an iron hoop, rotating in its own plane about the centre, should vary as the square of the speed. If the tensile strength of steel be 50 tons per square inch, find the greatest circumferential speed of a steel tyre (sp. gr. = 7·85).—*London University, Intermediate Engineering*, 1904.

Each particle of the hoop is constrained to revolve in a circular path, of which the radius is

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equal to that of the hoop. If we consider a particle at one end of a diameter of the circle, its instantaneous momentum is equal to $m\,v$, where m is the mass, and v the linear velocity of the particle. When the hoop has completed half a rotation, the particle will be at the opposite end of the diameter, moving with a velocity $(-v)$ (*i.e.*, in a direction opposite to its original direction of motion), so that its momentum is now equal to $(-m\,v)$; the change in its momentum during a half rotation of the hoop is, therefore, $2\,m\,v$. The average force acting on the particle during a half rotation of the hoop is equal to the *rate* of change of momentum; and since the change of momentum is proportional to v, and the time in which this change occurs is inversely proportional to v, it follows that the average *rate of change of momentum* is proportional to v^2. Since the hoop is prevented from breaking at opposite ends of a diameter by its tensile strength, it follows that the tension of the hoop is proportional to v^2.

Let a = sectional area of tyre, and $2l$ its circumferential length. A short element, of length dl, will have a mass $\rho a.dl$, where ρ is the density (mass per unit volume) of the tyre. If v is the circumferential velocity of the tyre, the velocity of the element will change from $(+v)$ to $(-v)$ in a time l/v (the time required for half a rotation of the tyre). Thus average rate of change of momentum of element during a half rotation of the tyre $= (2\rho a dl \times v) \div l/v = 2\rho a v^2\,dl/l$. Thus the average force acting on an element is proportional to the length dl of the element. At a given instant the length of the part of the tyre on one side of a diameter is equal to l, and each of its elements is, on an average, acted on by the force obtained above. Hence the total force, at any instant, which tends to break the tyre at opposite ends of a diameter is equal to

$$\frac{2\rho a v^2 l}{l} = 2\rho a v^2 \quad . \quad . \quad . \quad (1)$$

Let T = tensile strength of tyre, in dynamical units of force per unit area. Then since the sections of the tyre which must sustain the force (1) have an area of $2a$, we have, for the condition that the tyre should just be on the point of breaking :—

$$2\,T\,a = 2\rho\,a\,v^2;$$

$$\therefore T = \rho v^2;\ \therefore v = \sqrt{\frac{T}{\rho}}$$

50 tons = 50 × 2,240 × 32 = 3,584,000 poundals. Therefore 50 tons per square inch $= 3{\cdot}58 \times 10^6 \times 12^2$ poundals per square foot. One cubic foot of water weighs 62·3 lbs. nearly; ∴ the density of a substance having a sp. gr. of 7·85 is equal to 62·3 × 7·85 = 489 lbs. per cubic foot. Therefore,

$$v = 12\sqrt{\frac{3{\cdot}58 \times 10^6}{489}} = 1026 \text{ feet per sec. (nearly).}$$

HYDRO-DYNAMICS.—When a fluid flows through a horizontal pipe of which the diameter varies from point to point, it is found that the pressure is less at the narrow than at the wider sections. Is it possible to give an explanation of this phenomenon which does not involve the use of mathematics?

Consider any portion of the pipe in which the diameter varies. Let imaginary planes, perpendicular to the line of flow, be drawn across a wide and a narrower section; then since there is no progressive accumulation of fluid between the planes, it follows that equal quantities of fluid must flow across both sections in equal times. Consequently the velocity of the fluid crossing any section of the pipe must be inversely proportional to the area of that section; so that when a particle flows from a wide to a narrower part of the pipe its velocity increases, while its velocity decreases as it passes from a narrow to a wider portion of the pipe. Now if the pipe were uniform in section, and friction were absent, the pressure would be uniform all along the pipe; in these circumstances the velocity of a particle of the fluid would be constant, and since a difference of pressure on opposite sides of the particle would cause its velocity to change, we see that no such difference of pressure can exist. When the velocity of a particle increases, the pressure in front of it must be less than that behind it; when the velocity of a particle diminishes, the pressure in front of it must be greater than that behind it. Consequently the fluid, in passing from a wide to a narrower section, must pass from a point at a high to one at a lower pressure: as it passes from a narrow to a wide section, it must pass from a point at low to one at a higher pressure. Hence we deduce the important hydro-dynamical law, "Where the velocity is greatest the pressure is least."

ROTARY CONVERTER PROBLEM.—A star-connected 3-phase alternator giving 1,500 volts per phase supplies 6-phase current by means of three delta connected transformers, each provided with two equal secondaries. The current is passed into a rotary converter supplying direct current at 550 volts. Calculate the change ratio of the transformers and the current supplied by each of the secondaries if 200 kw. are taken from the converter. Neglect magnetic leakage and loss in transformation. Show by diagram how the six contact rings of the converter are connected to the secondaries.—(*B.Sc. Engineering*, 1903, *London University*.)

The connections for the 6-phase current rotary converter installation referred to in this problem are shown in Fig. 1, from which it will be seen that the principle employed is that of using two distinct mesh connections, one superposed upon the other, the two meshes being in electrical connection through the armature windings of the converter. It is obtained from three single-phase transformers, T_1, T_2, and T_3, similar in all respects, each being wound with two equal secondary windings. The 3-phase star-connected alternator is denoted by G in the figure, and the three secondary windings a, c, and e of the transformers T_1, T_2, and T_3 are mesh connected,

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and led to the three slip-rings 1, 2, and 3 in connection with the armature winding of the rotary, 120° (electrical) apart, while the three secondaries *b*, *d*, and *f* are also connected, but in the opposite direction; the three conductors from the points of the mesh are taken to the remaining three slip-rings, 4, 5, and 6, on the shaft of the rotary (there are six slip-rings on the rotary), which are in connection with points on the armature winding lying midway between the tappings to the three slip-rings 1, 2, and 3. A little consideration will show that, in these circumstances, the two meshes differ half a cycle (180°) from one another, and consequently satisfy the 6-phase condition.

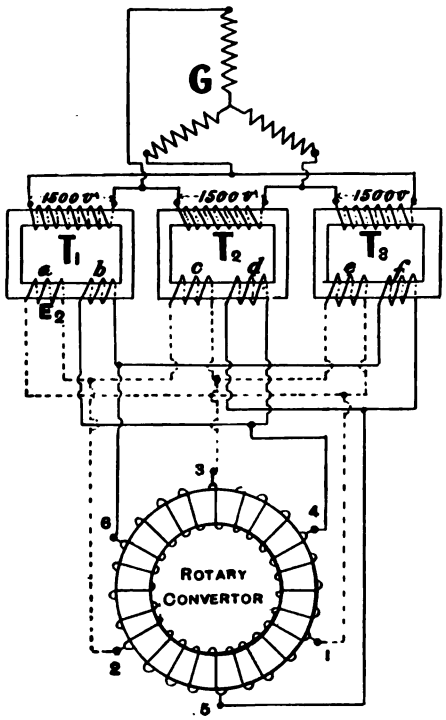

FIG. 1.—ROTARY CONVERTOR.

As the output of the rotary converter, in the form of continuous current at 550 volts is given (*i.e.*, 200 kw.), it will be the best plan to work backwards, and deal with the relationship between the continuous and alternating virtual voltages and currents of the rotary converter, which are, as is well known, practically fixed. Assuming that the magnetic flux is distributed as a sine function with respect to the periphery of the armature, and that internal losses and inductive effects may be neglected, it may be shown that

$$E_a = \frac{E}{\sqrt{2}} \sin \frac{\pi}{n}$$

$$C_a = 2\frac{\sqrt{2}\,C}{n}$$

in which E and C denote the pressure and current on the continuous side of the rotary; E_a and C_a the virtual voltage between adjacent slip-rings and the virtual amperage supplied to each slip-ring, and n denotes the number of slip-rings.

From the conditions given $n = 6$, E = 550 volts, and $C = \frac{200 \times 1000}{550} = \frac{4000}{11}$ amperes, therefore by substitution we obtain

$$C_a = \frac{2\sqrt{2}}{6} \times \frac{4000}{11} = 171{\cdot}4 \text{ virtual amperes,}$$

and $E_a = \frac{550}{\sqrt{2}} \sin 30°$

$= 194{\cdot}4$ volts.

In words, the P.D. between the slip-rings 1–5, 5–2, etc., is 194·4 volts, and the phase relation between these P.D.'s is 60°. If the E.M.F. supplied by each section of the secondaries of the transformers be E_2, it is obvious that E_2 will be the resultant of two equal P.D.'s of 194·4 volts differing in phase by 60°, consequently

$$E_2 = \sqrt{3} \times 194{\cdot}4 \text{ volts,}$$

and if *k* denotes the ratio of transformation,

$$k = \frac{\sqrt{3} \times 194{\cdot}4}{1500} = 0{\cdot}224$$

$$= \frac{1}{4{\cdot}4},$$

or, in words, the number of turns in the primary winding of each transformer will be 4·4 times the number forming each section of the secondary windings.

As regards the current supplied by each, it must be noted that the 171·4 virtual amperes received by each slip-ring of the converter is the resultant of two equal currents 120° apart supplied by two secondary sections connected in mesh combination, therefore the current supplied by the secondaries will be

$$C_2 = \frac{171{\cdot}4}{\sqrt{3}} = 98{\cdot}95 \text{ amperes.}$$

DIFFERENTIATION.—If $y = \sin \theta$, prove that $dy/d\theta = \cos \theta$, by aid of the relation $\sin^2 \theta + \cos^2 \theta = 1$.

With C as centre, and unit radius, draw the circle A B D E (Fig. 1). Let the radius C F make an angle, of which the circular measure is θ, with the fixed radius C A. Draw F L perpendicular to C A, then since C F = 1, it follows that C L = $\cos \theta$, while L F = $\sin \theta$, and $(C L)^2 + (L F)^2 = \cos^2 \theta + \sin^2 \theta = 1$.

Draw the radius C G making a small angle F C G = $d\theta$ with C F. Drop the perpendicular G M on C A, and from F draw F K perpendicular to G M, intersecting the latter line in K. Then if L F = y, it follows that M G = $y + dy$, and therefore K G = dy. Further, since the circle A B D E is of unit radius, and the circular measure of the angle F C G = $d\theta$, it follows that F G = 1 × $d\theta$ = $d\theta$. If the angle F C G

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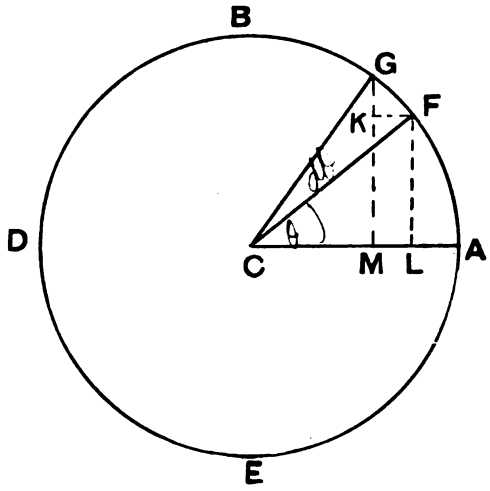

FIG. 1.—DIFFERENTIATION.

is indefinitely small, the arc F G will approximate to a straight line, and G F K will approximate to a small right-angled triangle. Then

$$\frac{dy}{d\theta} = \frac{K G}{F G} = \cos F G K.$$

Now since F G is an arc of the circle A B D E it must be perpendicular to the radius C F; also, by construction, G M is perpendicular to C A. Hence the angle F G K, between the lines F G and G M, is equal to the angle between C F and C A; *i.e.*, the angle F G K = θ. Consequently

$$\frac{dy}{d\theta} = \cos\theta$$

ZEEMAN EFFECT.—Give a general account of the appearance presented by the spectroscopic examination of the radiation from an incandescent gas in a strong magnetic field.—*Board of Education, Electricity and Magnetism, Honours*, 1902.

If the light emitted by an incandescent gas is analysed by means of a spectroscope of high dispersive power, it is found that a marked change is produced in the spectrum when a strong magnetic field is formed in the space occupied by the gas. This phenomenon was first observed by Zeeman, and is therefore called the *Zeeman effect;* it was previously predicted by Lorenz. To explain the appearance presented, it will be best to first give a brief sketch of the theory of the phenomenon. When a small electrically-charged particle moves in a circular path, it is to all intents and purposes equivalent to a circular circuit carrying an electric current. Let us suppose that we are looking down on a small positively charged body revolving in a right-handed or clockwise direction in a horizontal plane. If a magnetic field, acting vertically downwards, is produced by the aid of a magnet, then the orbit of the particle will expand: a flexible and extensible electric circuit carrying a current in a clockwise direction would do the same in similar circumstances. The linear velocity of the particle, however, remains constant, with the result that a smaller number of revolutions will be made per second. By similar reasoning a (+) charged particle revolving in an anti-clockwise direction would have its orbit diminished in diameter in similar circumstances, and would therefore make a greater number of revolutions per second. The orbit of a particle revolving in a vertical plane (*i.e.*, a plane parallel to the magnetic field) would not be changed in diameter.

Now according to the theory of Lorenz, the emission of light by a glowing gas is due to the motions of small electrically-charged particles; the number of revolutions per second of a particle will determine the number of waves produced per second. If we could view one of the particles, looking at it along a diameter of its orbit, we should see a line of light; the direction of vibration of the waves would be parallel to the plane of its orbit. If all particles revolve in one given period in the absence of a magnetic field, then there will be only one period of vibration for the resulting light; in other words, light of one wave-length will alone be produced, and the spectroscope will give one bright line. Let us suppose that the magnetic field is now produced, and that we look at the incandescent gas perpendicular to the lines of force of the field (*i.e.*, that we look at the gas in a horizontal direction). The particles revolving in vertical planes will emit waves of the same length as previously, and the direction of vibration in these waves will be *vertical*. The particles revolving in horizontal planes will emit waves of greater or smaller length than those originally emitted, according as their orbits are enlarged or diminished by the magnetic field. Hence these particles will produce waves vibrating *horizontally*, some of which are longer, and some shorter than those normally emitted. Consequently, looking at the gas in a direction perpendicular to the lines of force of the field, the spectroscope will reveal *three* adjacent lines instead of the one observed originally; the two outer lines, corresponding to the waves of augmented and diminished length, will be polarised in a plane perpendicular to the central line, which corresponds to waves of the normal length. This is exactly what was observed by Zeeman.

If this incandescent gas is viewed in a direction parallel to the lines of force, the particles (if they could be seen) would be observed to follow circular orbits in a plane perpendicular to the line of vision; in this case, two lines take the place of the one observed by the aid of the spectroscope under ordinary conditions, and the light corresponding to each is circularly polarised, the directions of polarisation of one line being opposite to that of the other. Subsequent researches have shown that in some cases more complicated results are observed. Certain lines are not decomposed at all by the magnetic field; some are decomposed as above described; while finally some lines are decomposed into more than three lines. There is little doubt,

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however, that Lorenz's theory is in the main correct ; there are probably other causes of a more complicated nature which produce the discrepancy observed.

INTEGRAL.—Prove that

$$\int_0^{\pi} \frac{x \tan x}{\sec x + \tan x}\, dx = \frac{\pi^2}{4} \text{ (Edwards, p. 133).}$$

If I denote the given integral, then

$$I = \int_0^{\pi} \frac{x \sin x}{1 + \sin x}\, dx.$$

Let $x = \pi - z$, then

$$I = -\int_{\pi}^{0} \frac{(\pi - z)\sin z}{1 + \sin z}\, dz$$

$$= \int_0^{\pi} \frac{(\pi - z)\sin z}{1 + \sin z}\, dz$$

$$= \pi \int_0^{\pi} \frac{\sin z\, dz}{1 + \sin z} - I ;$$

$$\therefore\ 2I = \pi \int_0^{\pi} \frac{\sin z\, dz}{1 + \sin z}$$

$$= \pi \int_0^{\pi} \frac{1 + \sin z - 1}{1 + \sin z}\, dz$$

$$= \pi^2 - \pi \int_0^{\pi} \frac{dz}{1 + \sin z}$$

$$= \pi^2 - \pi \int_0^{\pi} \frac{\sec^2 \frac{z}{2}\, dz}{\left(1 + \tan \frac{z}{2}\right)^2}$$

$$= \pi^2 - 2\pi \int_0^{\pi} \frac{d\left(\tan \frac{z}{2}\right)}{\left(1 + \tan \frac{z}{2}\right)^2}$$

$$= \pi^2 - 2\pi \left[-\frac{1}{1 + \tan \frac{z}{2}} \right]_0^{\pi}$$

$$2I = \pi^2 - 2\pi.$$

Hence $$\int_0^{\pi} \frac{x \tan x}{\sec x + \tan x}\, dx = \frac{\pi^2}{2} - \pi.$$

The answer given in question appears to be wrong. There is no general method for integrals of this character, but the above substitution of $\pi - z$ for x will frequently simplify integrals. An analogous method would be to put $x = \frac{\pi}{2} - z$, and $x = \frac{\pi}{2} + y$ in succession, and after simplification and addition we should arrive at

$$2I = \pi \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\cos y}{1 + \cos y}\, dy,$$

which gives the result obtained before.

DYNAMICS.—In solving the equation for the rectilinear motion of a particle under the influence of a force which varies inversely as the n th power of the distance, we have to integrate

$$(a^{n-1} - x^{n-1})^{-\frac{1}{2}} x^{\frac{n-1}{2}} dx.$$

According to the tests of integrability this may be done when

$$n = \ldots\ \tfrac{4}{3}, \tfrac{3}{2}, \tfrac{2}{1}, -1, \tfrac{1}{2}, \tfrac{1}{3} \ldots$$

and when

$$n = \ldots\ \tfrac{4}{3}, \tfrac{3}{2}, \tfrac{2}{1}, 0, 2, \tfrac{1}{2} \ldots$$

Will you please explain what these tests are, and how they are applied to this example ?

The given differential is of the form

$$x^m(A + Bx^q)^p dx,$$

and is known as the Binomial Differential.

(1) Let $z = A + Bx^q$,

then $$x = \left(\frac{z - A}{B}\right)^{\frac{1}{q}}$$

and $$dx = \frac{1}{qB}\left(\frac{z - A}{B}\right)^{\frac{1}{q} - 1} dz.$$

Hence

$$x^m(A + Bx^q)^p dx = \frac{(z - A)^{\frac{m+1}{q} - 1} z^p dz}{qB^{\frac{m+1}{q}}}$$

If, then, $\frac{m + 1}{q}$ is a positive integer, we may, by aid of the Binomial Theorem, obtain the solution in a finite number of terms.

Again, integrating by parts and rearranging terms,

$$\int x^m(A + Bx^q)^p dx$$

can be made to depend on *any one* of the four integrals

$$\int x^{m-q}(A + Bx^q)^p dx, \quad \int x^m(A + Bx^q)^{p-1} dx,$$

$$\int x^{m+q}(A + Bx^q)^p dx, \quad \int x^m(A + Bx^q)^{p+1} dx.$$

The first of these is integrable when

$\frac{m - q + 1}{q}$ is a $+^{ve}$ integer,

the second when $\frac{m + q + 1}{q}$ " " "

Hence the given differential can be integrated when $\left(\frac{1}{n-1} + \frac{1}{2}\right)$, or $\left(\frac{1}{n-1} - \frac{1}{2}\right)$, or $\left(\frac{1}{n-1} + \frac{3}{2}\right)$ is a $+^{ve}$ integer. The first two can be obtained from the third by subtracting 1, and since integration by parts may be performed any finite number of times, we have the condition $\left(\frac{1}{n-1} - \frac{1}{2}\right)$ = a positive or negative integer, or zero.

Hence, putting

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$$\frac{1}{n-1} - \tfrac{1}{2} = 0, 1, 2, 3 \ldots .$$

and $$= -1, -2, -3, \ldots .$$

in succession we obtain

$$n = 3, \tfrac{5}{3}, \tfrac{7}{5}, \ldots .$$

and $$n = -1, \tfrac{1}{3}, \tfrac{3}{5}, \tfrac{5}{7}, \ldots .$$

or together

$$n = \ldots . \tfrac{5}{7}, \tfrac{3}{5}, \tfrac{1}{3}, -1, 3, \tfrac{5}{3}, \tfrac{7}{5} \ldots .$$

(2) If in the original differential we substitute $x = \frac{1}{y}$, we obtain

$$-y^{-pq-m-2}(Ay^q + B)^p dy,$$

and this by preceding rule is integrable when

$$-\frac{m+1}{q} - p \text{ is a positive integer,}$$

and this can be extended by the second and fourth integrals of (1) to the cases where

$$-\frac{m+1}{q} - (p \pm 1)$$

is a positive integer, or generally to the case where this is a positive or negative integer. Putting in our values for m, p, and q, we get

$-\frac{1}{n-1}$ must be a positive or negative integer.

Hence $n = 2, \tfrac{3}{2}, \tfrac{4}{3}, \ldots .$

and $n = 0, \tfrac{1}{2}, \tfrac{2}{3}, \tfrac{3}{4} \ldots .$

and generally

$$n = \ldots . \tfrac{3}{4}, \tfrac{2}{3}, \tfrac{1}{2}, 0, 2, \tfrac{3}{2}, \tfrac{4}{3} \ldots .$$

It should be noted that we have proved the integrability when n has certain values, but not that these exhaust the possible values.

Will the correspondent who furnished query under nom-de-plume of "Fluid Pressure" please forward name and address.

TECHNICS CORRESPONDENCE.

RESISTANCE OF METALS AT LOW TEMPERATURES.

To the Editor of TECHNICS.

DEAR SIR,—My attention has been drawn to the letter of Mr. R. Macdonald in the August number of your journal. The researches referred to by Mr. S. Irwin Crookes are no doubt those which are given in a paper by Professor Sir James Dewar, namely, the Bakerian Lecture on "The Nadir of Temperature and Allied Problems," delivered before the Royal Society on June 13th, 1901.

I am, yours faithfully,
HENRY YOUNG.

21, Albemarle Street, W.
August 30th, 1904.

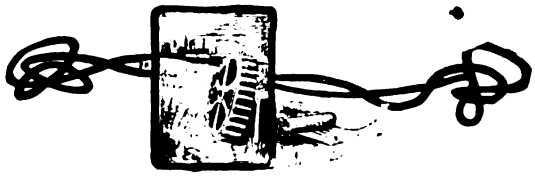
To the Editor of TECHNICS.

DEAR SIR,—In your July number you give an interesting statement of the space occupied by various sizes of oil and gas engines compared with electric motors.

For oil you state that a 20 B.H.P. engine requires 85 square feet. You do not, however, take into account the Diesel Oil Engine, and we should like to point out that a 20 B.H.P. engine of this type requires only a floor space of 44 square feet. On a space of 114 square feet we can erect one of our 80 B.H.P. engines.

Yours faithfully,
HAROLD FOORD,
Secretary Diesel Engine Co., Ltd.

179, Queen Victoria Street,
August 23rd, 1904.



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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded to the "Technics" Prizeman.

£25 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 94 competitions have been given in the preceding nine numbers of TECHNICS.

The present number contains particulars of 7 competitions, for which money prizes amounting, in the aggregate, to £25 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£25 IN PRIZES.

General Rules.

Competitors are requested to note the following rules:—

All writing must be on foolscap paper, only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must be executed in black ink, and not shaded in wash, or coloured.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, TECHNICS, 12, Burleigh Street, Strand, W.C., and must reach these offices not later than November 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

CHEMISTRY.

£3 for the best answer.

Describe the latest method of producing sulphuric acid, giving diagrams of the plant used.

ENGINEERING.

£3 for the best answer.

Describe the methods of utilising forced draught and induced draught; discuss the relative advantages of each method, giving diagrams.

ELECTRICAL ENGINEERING.

£3 for the best answer.

Discuss the characteristic features of boosters designed for various purposes, giving diagrams.

COTTON SPINNING.

£3 for the best answer.

Give tables exhibiting the production of machines in a modern cotton mill: using, so far as possible, information gained by personal experience.

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EXPANSION CURVES.

£1 10s., £1, and 10s. for the three best answers in order of merit

Draw on a larger scale the expansion curve in the indicator diagram forming part of Fig. 2, p. 370. Assuming the equation to this curve is of the form $p v^n = c$, find the clearance as a fraction of the volume swept out by the piston, and determine the best average values of n and c.

ELECTRO-MAGNETIC THEORY.

£5 for the best set of answers.

1. An electroscope is charged inductively by means of a glass rod, which has been rubbed by flannel. Give sketches showing the disposition of the lines of force at each stage of the process.

2. A small charged body is hung by a silk thread inside an insulated, uncharged, spherical metal shell. Sketch the lines of force, inside and outside the shell, when (1) the charged body is at the centre of the shell, and (2) when it is near the walls of the shell.

3. Draw the lines of force due to a charged conductor pointed at one end. Explain exactly why the surface density of the electrification is greater near the point than elsewhere.

4. Explain, by the aid of lines of force, why an electrified body gives up the whole of its charge when it is lowered into, and allowed to touch the internal walls of a hollow insulated conducting vessel.

THEORY OF STRUCTURAL DESIGN.

£5 for the best set of answers.

1. Show that Equations XXXIV. and XXXV. give similar results under the conditions stated in the article in the current number.

2. In taking out the cross-sectional areas of built-up pillars, should we make any allowance or deduction for the rivet-holes? Give reasons.

3. Show why the factor of safety for a live load is double the factor of safety for a dead load. Illustrate your answer by sketches or diagrams where possible.

4. Describe in detail the best method of bedding large pillar base-plates on the foundation block. Do you prefer layers of felt, lead sheets, steel wedges and cement grouting; or do you prefer some alternative method? Give your reasons. State the disadvantages of the methods you reject

RESULTS OF JULY COMPETITIONS.

RADIUM.

PRIZE, £3.—Edgar P. Hedley, Royal College of Science, Dublin.

SPECIAL HONOURABLE MENTION :— S. Irwin Crookes ; E. Walls.

HONOURABLE MENTION :—Harry Hutchinson ; Christopher Hollyoak ; Harold Slicer ; James Augustus Robertson ; H. H. Francis Hyndman.

STORAGE OF ENERGY.

PRIZE, £3.—H. A. Stewart, Sunnyside, York Road, Southend-on-Sea.

COTTON SPINNING.

PRIZE, £3.—J. E. Tytler, 26, Meller Road, Slade Lane, Longsight, Manchester.

SPECIAL HONOURABLE MENTION :—Herbert Wroe ; Frederic Stones.

ARC LIGHTING.

PRIZE, £3.—Frank Shaw, 6, May Street, Chorlton-on-Medlock, Manchester.

SPECIAL HONOURABLE MENTION : — A. J. Aldridge ; John Wilson ; H. E. Hodgson ; M. J. Tweedie.

HONOURABLE MENTION :—Thomas J. Sack ; H. A. Stewart ; H. H. Francis Hyndman ; William Kingston ; John F. Punch ; S. Irwin Crookes ; Ernest Cook.

MECHANICAL ENGINEERING (Gas Engines).

PRIZE, £3.—H. E. Hodgson, 6, Devonshire Street, West Kensington, W.

SPECIAL HONOURABLE MENTION :—H. G Lester.

MECHANICS OF THE GYROSCOPE.

PRIZE, £5.—D. H. Bishop, c/o Mrs. Logan, 2, Blackness Crescent, Dundee.

SPECIAL HONOURABLE MENTION :—Thomas Royds ; J. M. Young ; Harry Hughes Harrison ; William R. McLaughlin ; Robert H. Buckie.

HONOURABLE MENTION : — A. E. O'dell ; Fred. Pickford ; Fred. Mayer ; C. H. Chambers ; Thomas Clough ; J. Mitchel McLean ; A. Richards.

THEORY OF STRUCTURAL DESIGN.

PRIZE, £5.—K. Bonallo, 29, South Street, Greenwich.

SPECIAL HONOURABLE MENTION :—D. E. Synan ; Henry J. Jones.

HONOURABLE MENTION : — H. Kenward ; William Matthews ; Harold Slicer.

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PERSONAL ITEMS.

MESSRS. BOLCKOW, VAUGHAN AND CO., colliery owners, have placed an order with Messrs. Graham, Morton and Co., Ltd., Hunslet, Leeds, for the extension of the contract to instal a complete coal-screening plant and all necessary structural work for the Dean and Chapter New Colliery, Bishop Auckland, Co. Durham. The extension is for the roofing-in of the Dean and Chapter Pits.

WE recently reviewed Jamieson's Elementary Manual on "Steam and the Steam Engine"; we understand that Messrs. Charles Griffin and Co. have just brought out the sixth edition of the same author's manual on "Applied Mechanics," which is a companion book to the former. They also hope to issue the fourteenth enlarged and thoroughly revised edition of Jamieson's text-book on "Steam and Steam Engines," including steam turbines and boilers, and the seventeenth edition of Munro and Jamieson's Pocket-book of "Electrical Rules and Tables," with the submarine cable and other sections up to date.

ENGINEERING is taught by correspondence, and students are prepared for examinations and situations, by Professor A. Jamieson, M.Inst.C.E., Kelvinside, Glasgow.

WE have received from the Cambridge Scientific Instrument Company, Ltd., their list No. 25 of Technical Thermometry, which is a new and revised edition of a catalogue issued some time ago. Copies can be obtained by application to the works, Carlyle Road, Cambridge, England.

THE Board of Education has received from the French Government a notification of their intention to attach as temporary assistants to certain *lycées* a number of young English secondary schoolmasters, or intending schoolmasters who have undergone an approved course of training and hold some recognised diploma for secondary teachers. These assistants will conduct small conversation groups under the direction of the *proviseur*. Two hours' work a day will be expected of them. The rest of their time will be at their own disposal, so that they will thus be able to pursue their own studies. The assistants will receive no remuneration, but will be boarded and lodged at the institutions to which they are attached. Candidates for such posts should forward their application to the Director of Special Inquiries and Reports, St. Stephen's House, Cannon Row, S.W., enclosing testimonials as to character, capacity, and teaching experience, and a medical certificate of health. It will also be necessary for each candidate to have a personal interview with the director at his office, and should any candidate have any special desire as to date of interview, it would be well to indicate it when forwarding the application.

WE regret that in the results of the May and June competitions the name of Mr. A. G. Lee, of Page Moss House, Knotty Ash, Liverpool, was wrongly printed as A. Ghee.

MR. EDGAR SENIOR'S classes on photography at the Battersea Polytechnic will be held on Tuesdays (elementary) and Thursdays (advanced), from 7.30 p.m. to 10 p.m. The classes include practical work. The first class was held on September 27th.

MR. J. HARCOURT BROWNE is lecturing at the Battersea Polytechnic on paper-making, on Fridays, from 8 p.m. to 9 p.m. The first lecture was held on September 30th.

MR. R. W. SINDALL, F.C.S., is lecturing on paper-making and paper-testing at Exeter Hall, Strand, during October, November, and December, 1904. The elementary course will be delivered on Thursdays, and the advanced course on Fridays, commencing at 7.30 p.m. The syllabus we have received shows that the lectures will come up to the high standard expected from Mr. Sindall, being illustrated with specimens, lantern views, and experimental demonstrations.

THE Society of Chemical Industry this year held its annual meeting at New York. Sir Sir William Ramsay's presidential address contains the following interesting utterance on the subject of examinations as a test of education :—"The older I get the less I believe in university degrees as a test of capacity. . . . The qualities tested by such examinations as have been customary for the past forty years in England, are the last which one would wish to have in a student of science —readiness of memory to the exclusion of deliberate judgment; the faculty of spreading knowledge thin, and making a veneer of scientific facts instead of the power to correlate them and increase their value; and the skill to gauge the capacity of and hoodwink the examiner, instead of the power to incite enthusiasm in others. They are ideal qualities for a successful barrister, because they pay in his profession; but their reward has been the bane of science. A sound judgment, though it may be a slow one; persistence in struggling against obstacles; the knowledge where to get information when required, and to use it when found; and the inventive faculty—these are the qualities required, and they can be gauged only after long-continued observation."

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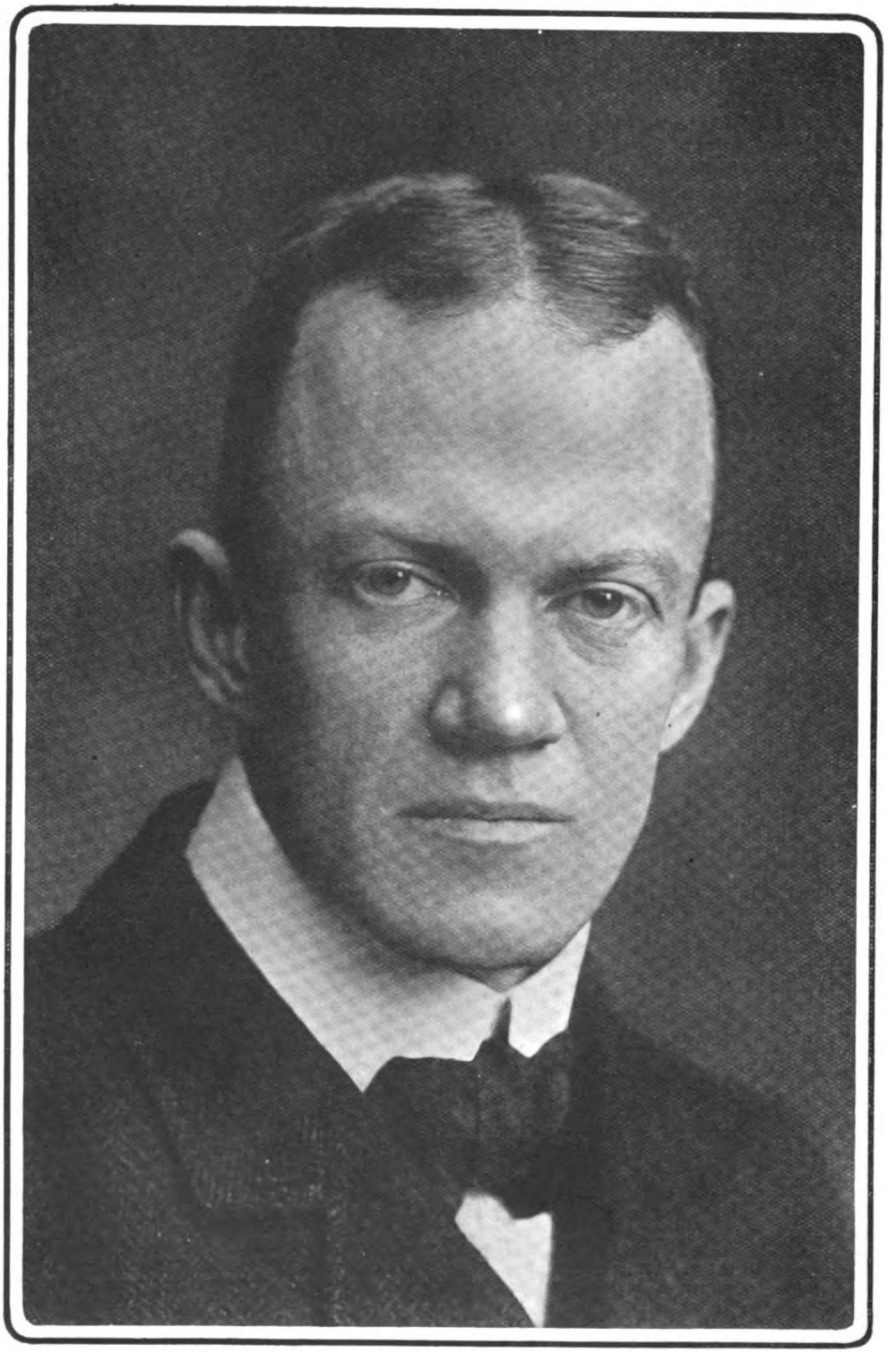

H. M. HOBART, M.I.E.E.

Photo. by Geo. Newnes, Ltd.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. II. NOVEMBER, 1904. No. 11.

PROGRESS OF SCIENCE AND TECHNOLOGY.

IN a letter from Mr. S. Skinner, printed in *Nature*, October 6th, it is stated that Mr. H. Cottam, of the South-Western Polytechnic, Chelsea, has examined the radio-activity of specimens of the London clay from various districts, brought to the surface during the "tube" operations in London. All of these samples were found to be destitute of radio-activity. On the other hand, water from the deep well belonging to Messrs. Eastman, Latimer Road, W., was found to be distinctly radio-active; the water is derived from the greensand lying below the clay. Hence it appears that radio-active substances can travel through the crust of the earth only with water, so that the London clay forms a floor through which they cannot penetrate.

Radio-active Water

PROFESSOR R. W. WOOD contributes an interesting letter to *Nature*, of September 29th, in which he states that he has recently visited "one of the laboratories in which the apparently peculiar conditions necessary for the manifestation of this most elusive form of radiation [N rays] appear to exist." Professor Wood's experiences at this laboratory appear to throw the gravest doubts on the objective existence of N rays. The following is an account of experiments shown:—"I was next shown the experiment of the deviation of the rays by an aluminium prism. The aluminium lens was removed, and a screen of wet cardboard, furnished with a vertical slit about three millimeters wide, put in its place. In front of the slit stood the prism, which was supposed not only to bend the sheet of rays, but to spread it out into a spectrum. The positions of the deviated rays were located by a narrow vertical line of phosphorescent paint, perhaps 0·5 millimeter wide, on a piece of dry cardboard, which was moved along by means of a small dividing engine. It was claimed that a movement of the screw corresponding to a motion of less than 0·1 millimeter was sufficient to cause the phosphorescent line to change in luminosity when it was moved across the N ray spectrum, and this with a slit two or three millimeters wide. I expressed surprise that a ray bundle three millimeters in width could be split up into a spectrum with maxima and minima less than 0·1 of a millimeter apart, and was told that this was one of the inexplicable and astounding properties of the rays. I was unable to see any change whatever in the brilliancy of the phosphorescent line as I moved it along, and I subsequently found that the removal of the prism (we were in a dark room) did not seem to interfere in any way with the location of the maxima and minima in the deviated (!) ray bundle.

N Rays

"I then suggested that an attempt be made to determine, by means of the phosphorescent screen, whether I had placed the prism with its refracting edge to the right or left; but neither the experimenter nor his assistant determined the position correctly in a single case (three trials were made). This failure was attributed to fatigue."

Other experiments shown to Professor Wood were equally unsatisfactory.

THE activity of the emanation affords a very sensitive test for the presence of radium in uranium salts. Whetham states that specimens of uranium salts that were bought 17 to 25 years ago now contain more radium than those recently purchased. This result may, however, be due to modified methods of separation, and

Presence of Radium in old samples of Uranium salts

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Soddy has since stated that the accumulation of radium in a kilogramme of uranium nitrate in the course of twelve months amounts to less than 10^{-11} gram, and that this practically settles, in a negative sense, the question of the production of radium from uranium. The question is, however, of such vital importance to the disintegration theory that the results of further experiments will be awaited with very great interest.

Bacteria in Coal Gas

IT has recently been found that bacteria may exist in a pipe supplying illuminating gas, and that they may so act upon the sulphur compounds contained therein as to liberate sulphuretted hydrogen. The quantity of the sulpho-carbons permitted in London gas is about 20 grains per 100 cubic feet, but a smaller quantity than this is usually present. The presence of SH_2 is absolutely forbidden, and the tests in operation will indicate the presence of one part in one million of gas. It was by this delicate test that the presence of SH_2 was found in gas previously quite free from it. On examining the pipe leading to the Tudor Street gas testing station of the City of London, it was found that a hollow place allowed water to lodge: micro-organisms had developed in this water, and had converted some sulphur from the gas into the objectionable SH_2. The fact that bacteria generate SH_2 has been known for years, but the extension of our knowledge to an environment of coal gas, which contains carbon monoxide and hydro-carbons, is due to Mr. J. G. Tapley, one of the chemists of the Gas Light and Coke Company.

Coke Oven Gas

COKE oven gas is now being distributed to the inhabitants of Royston, near Barnsley. The gas is generated in recovery ovens of the Simon-Carves type, worked by the Monckton Main Colliery Company. A similar experience upon a smaller scale was obtained a few years ago at Brymbo, where Mr. J. H. Darby lighted his works by gas from Semet-Solvay ovens. Since then the practice has been developed in America, but Royston appears the only case where the project has been carried out upon a basis that may be expected to endure. The gas company purchase the gas (of about 6 to 12, with an average of 8 candle-power) from the colliery company, and then "benzolise" it until it is of 16 candles. Purifiers, a rotary meter, and the usual distributing plant have been erected, and the houses have all been fitted up with pipes and facilities for cooking stoves. This is but the beginning of what may be expected to grow into a large and profitable business in colliery districts. The wasteful old beehive oven is slowly but surely being superseded by a more rational system.

Purification of Gas by Ammonia

A SERIES of articles by Mr. Thos. Holgate, F.C.S., dealing with "The Purification of Gas by Ammonia," has just been concluded in the *Journal of Gas Lighting*. They show how the one alkaline constituent of the crude gas may be utilised to remove the acid constituents, and how this may be accomplished at much less cost than by the present methods of using lime. Carbonic acid and sulphuretted hydrogen are the chief impurities to be removed, and for these ammonia is an effective absorbent. The cost of purification in the year ended 31st December, 1903, by the three London companies, was £153,766; and in showing the saving per 1000 cubic feet of gas that has been effected upon the works where the ammonia system has been employed, the author points out that it would equal £60,000 per annum for London. The *modus operandi* is that of heating ammoniacal liquor to 200° F., when most of the CO_2 and H_2S previously absorbed becomes liberated, together with a small quantity of NH_3. The ammonia is absorbed by sulphuric acid to make sulphate of ammonia in the usual manner, whilst the H_2S is converted into "flowers of sulphur," or sulphuric acid, the latter being the best for large gasworks. The CO_2 escapes into the atmosphere, or may advantageously be collected and compressed into the liquid or solid form for sale.

The activity of the ammonia liquor, thus freed from its impurities, is increased fivefold; after cooling, it at once absorbs, in the ordinary "scrubbers" or "washers," large quantities of the acid gases CO_2 and and H_2S. The cost of revivification of the liquor, and all charges, both of working and capital, amount to 0·024*d.* per 1,000 cubic feet per 1 per cent. of CO_2 or H_2S abstracted —a sum only one-tenth of the cost ordinarily incurred. The average cost of the three London companies, in 1902 and 1903, was 1·07*d.* per 1,000 cubic feet of gas sold.

A NEW type of ball bearing recently introduced and put on the market by the Deutsche Waffen und Munitions-fabriken of

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Berlin will probably come extensively into use for all classes of work, from the lightest to the very heaviest. These bearings have been exclusively adopted by several prominent manufacturers of motor cars, who fit them

A New Ball Bearing

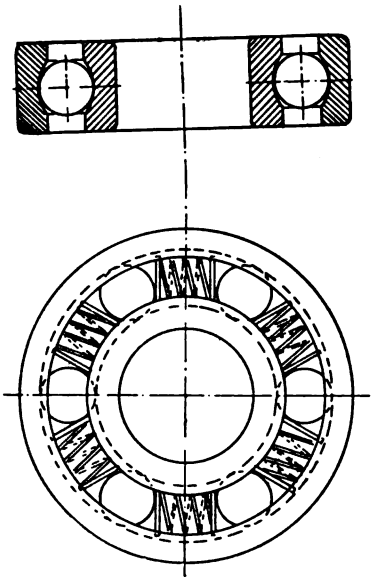

FIG. 1.—"DEUTSCHE" BALL BEARING.

throughout the running and transmission gear; experiments are being carried out to try if they can be fitted to crank-shaft and crank-pin

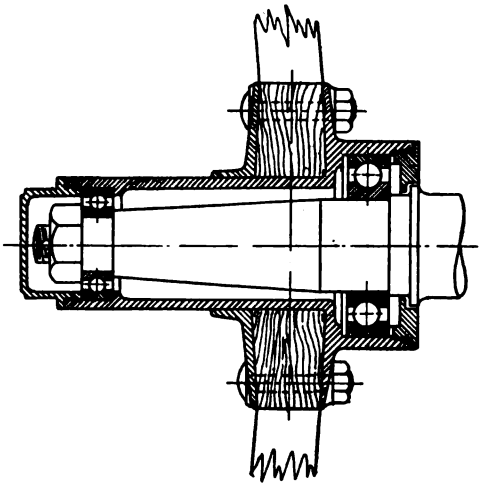

FIG. 2.—MOTOR-CAR HUB FITTED WITH "DEUTSCHE" BALL BEARINGS.

bearings, owing to the great saving of power that would be effected by their use. Fig. 1 shows one of these bearings in side view and section: it has numerous advantages over the usual "cycle type" of ball bearing. Each bearing is entirely self-contained, needs no adjustment, and has no wedging action on the balls; thus it does not wear if kept clean and lubricated, and can carry very heavy loads without injury. Both inner and outer races are hardened steel rings. The balls are separated by small spiral springs containing plugs of felt soaked in oil. The number of, and the distance between the balls is governed by the necessity for getting them into the races. As many as can be introduced without force are used, this being enough to go about three-fifths round the race; the remaining space is then filled up with the spiral springs, one between each pair of balls. These springs are of such a diameter that they cannot drop out of the races when in position. To get them in, their coils are pinched up close and then they are turned over and released. The springs are of such a length that they are quite free and do not press on the balls.

Ball Bearing Axles

FIG. 2 shows the latest type of motor-car hub fitted with "Deutsche" ball bearings. It will be noticed that only two rows of balls are used, a large bearing being located close under the spokes to take the greater part of the weight, and a smaller one further away, to steady the wheel and take the end thrust. The larger race is allowed a certain amount of side play, so that the balls run perfectly centrally in the grooves without any restraint. This hub is very much shorter than a standard "plain bearing" one, it runs with much less friction, and needs practically no attention. Great care is taken to exclude all dust and wet, as this would rapidly deteriorate the balls and races. The great advantage of ball bearings for axles is their small static friction, due to all the surfaces being in rolling contact. This allows of a mass being set in motion more readily; as an illustration of this a large motor car weighing over a ton, when fitted with these hubs, can be easily moved about by one man. The reduction of static friction enables a vehicle to be started with a smaller expenditure of power, and consequently the same sized engine will give a vehicle fitted with ball bearings a more rapid acceleration than would otherwise be possible.

AN ingenious power factor meter, or instrument for showing the average power factor of a polyphase circuit, is being made by the British Westinghouse Company, and is

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The Westinghouse Power Factor Meter

designed upon the following lines. Taking the simplest case, *viz.*, that of the two-phase instrument, A and B in Fig. 3 represent, in section, two coils at right angles to each other, which are respectively connected through series transformers, as shown, to the A and B phases of the circuit. M is a small pivoted electro-magnet, excited from either phase by means of a stationary fine

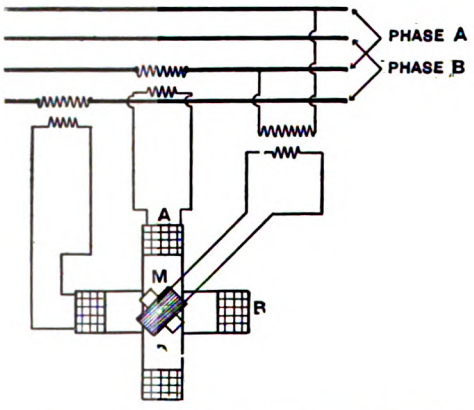


FIG. 3.—DIAGRAMMATIC REPRESENTATION OF WESTINGHOUSE POWER FACTOR METER.

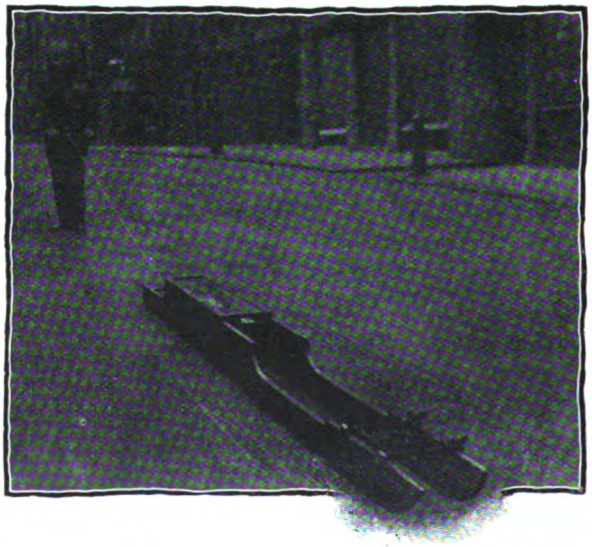
wire coil, after the manner of some revolving field alternators; its magnetic effect is thus in step with the voltage of the phase in which it is placed. As the phases under any condition of power factor are considerably out of step, it follows that a rotating field will be set up by the coils A and B. The magnetic field will be zero in the direction M B when the current in the coil A is zero, and in like manner it will be at its lowest value in the direction M A when the current in coil A is at its maximum; therefore, at any time between the maximum and zero of coil A, a zero field may be found between the points A and B. It follows that the magnet M, being attracted or repelled by the flux in coils A and B, will so place itself that its zero field will be produced concurrently with the zero of the rotating field. Thus, if its flux is in phase with the current of coil A, it will turn so that its axis is in the direction M B; while if it is 90° out, or in quadrature with the current in that coil, its axis will lie in the direction MA at right angles, and for any other phase relation between coils A and B its axis will lie in a corresponding position between the directions MA and MB. A pointer is fixed to the magnet, and this shows directly on a scale the cosine of the average angle of lag of the phases, which, though slightly different from the power factor of the circuit, is only negligibly so. The best results are obtained with a current of from 3 to 5 amperes in the coils A and B, and a voltage on M of from 75 per cent. to 125 per cent. of the normal, both of which figures can easily be arranged for by suitably proportioning the transformers. For three-phase circuits a third coil is added and connected to the other phase.

The VIAGRAPH (*Brown's Patent*) An Instrument for Measuring Road Wear

AN instrument which enables road surveyors to secure mathematically exact data concerning the wear on road surfaces cannot be too highly recommended to the notice of municipal authorities and associations interested in the improvement and maintenance of our highways.

The Viagraph is made in mahogany with gun-metal fittings, and is shaped like a sled, having parallel runners 12 feet long. When not in use, these runners can be folded back to half their length, by means of hinges, thus rendering the machine more portable for travelling.

Mounted between the runners, and protected by a glazed cover are the working parts, a combination of highly ingenious



[*Photo by C. Lavell.*

FIG. 4.—THE VIAGRAPH IN USE.

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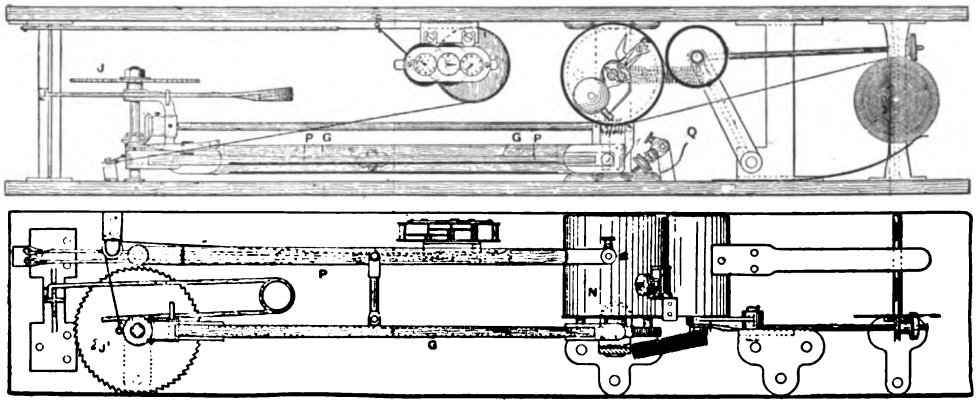

FIG. 5.—SECTIONAL PLAN AND ELEVATION OF VIAGRAPH.

devices which are, nevertheless, easily understood even by the lay mind. A steel-shod skate, shaped like a section of an ordinary cart-wheel of 40 inches diameter, and a small cogged wheel (J, Fig. 5), both of which are in continual contact with the surface to be tested, form the principal factors in this combination.

Inequalities in the road over which the Viagraph passes are communicated by the skate, through the medium of delicately adjusted levers (G and P) to a paper-covered cylinder (N, Fig. 5), upon which is

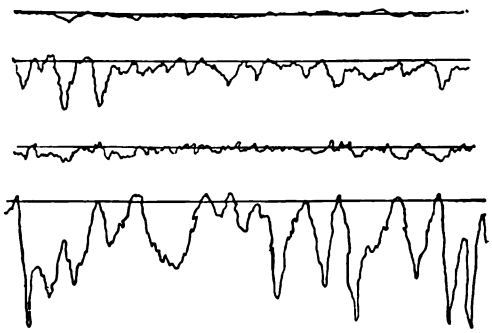

FIG. 6.—VIAGRAPH TRACINGS FROM DIFFERENT ROADS.

recorded by one pen (*a*, Fig. 5) a profile of the road traversed on a scale of $\frac{1}{8}$ inch to the foot. A second pen (shown Q, in dotted lines, in Fig. 5) indicates upon the same drum a datum line corresponding to that which the first pen would produce upon a perfectly even surface, and from this ruts or other unevennesses shown upon the scale can be measured. A system of decimal dials shows at a glance the sum of the depth of all the unevennesses; but, by an ingenious device, no upward movements are registered, that is, pebbles or other obstacles lying above the normal level do not affect the results. A ratchet wheel and a delicate triple pawl effect this ingenious and very necessary operation.

Now, it is obvious that in order to compare the record of one tested surface with another, the same length of each road must be taken as a unit, and for this purpose 88 yards, as being the $\frac{1}{20}$th of a mile, is measured off automatically; when this distance has been covered (33 inches of paper on the cylinder having received the resulting impression) a bell warns the operator.

In order to obtain trustworthy data as to the condition of a road, it is necessary to take several diagrams in succession along the tested surface.

The Viagraph is easily drawn by means of a cord attached to the front end, and reasonable care has to be employed to avoid twisting or jerking the instrument, either of which errors might affect its accurate working.

In disputes between contractors and municipal authorities, the value of such an infallible method of checking wear upon roads will be obvious. Eye inspection cannot be relied upon in such matters, for no two persons would so estimate the wear alike. And to bind contractors to definite quality in laying down and maintaining roads, the Viagraph affords undeniable proof of its merits, for by its use any excess in the wear indicated indisputably convicts the contractor of neglect.

Messrs. Glenfield & Kennedy, Limited, of Kilmarnock, to whose courtesy we are indebted for illustrations reproduced here, are the makers.

A NEW method for the decomposition of fats into glycerin and fatty acids furnishes

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Fat Splitting by Ferments

an interesting example of successful application of work in pure science to chemical industry. The discovery that there is an enzyme in castor seeds, which induces fatty substances to break down, in an exactly similar way to that well known in the glucosides, was made by an English worker, Russell. The industrial application, however, as has so often been the case, was German. On the experimental scale it is sufficient to mix the oil with castor seed and acetic acid in a small bottle, shaking at intervals. Progress can be ascertained by taking out a small portion at intervals, and shaking to find the quantity of free fatty acid. It appears that a balanced action tends to set in: the maximum yield is a question of the concentration, and the amount of water added is therefore of importance.

On the large scale quite simple apparatus is needed. An enamelled or aluminium pot (aluminium is expensive, but is hardly affected by free fatty acids), provided with a steam jacket and leaden coil for stirring by an air blast, is all that is necessary.

A small charge of 100 kilos. of cotton seed oil, for example, is placed in the pot. In another vessel 30 kilos. of water is acidified by adding 90 grams acetic acid, to which 5 kilos. of the castor seed is added. For convenience of working, the seed should be decorticated in a grinder and crushed very fine. On mixing with the acid liquor, at a temperature not exceeding 40°C., a milk of the consistency of whitewash is obtained. After settling for some time to get rid of husks, the liquor is thoroughly mixed with the oil, using the blast for about 12 hours, with the same care about the temperature. (If dealing with solid oils like palm kernel oil, there is no need to melt: a wooden stirrer will keep them in a workable condition.)

After this, the mixture is allowed to stand another working day, and then heated by the jacket to 80°C. About 1·5 kilos. of hot dilute sulphuric acid (1:5) is run in, and stirred with a wooden stirrer. Finally, the whole mixture is allowed to settle for three hours, with occasional stirring.

By this time there is separation into three layers:

Fatty Acids.
Middle Layer.
Glycerin Water.

Most of the bottom layer is now drawn off. The rest is washed three times with hot water, and allowed to settle again. The glycerin water is of the usual strength of spent lyes, and can be concentrated by a rotary evaporator, using waste steam. It is very pure, free from hyposulphites and chlorides.

To the fatty acid and middle layer residue, 10 kilos. of saturated brine solution is added (this is a recent improvement by Hoyer, of Charlottenburg, and has the effect of clearing the fatty acid emulsion). It is drawn off after three hours.

The middle layer, consisting of seed, fatty acid, and some neutral oil, is saponified in the usual way. The waste seed is found, partly in the nigre; the nitrogenous matter disappears as ammonia. The residue is pure fatty acids ready for soap-making or for candle stearine. The yield of fatty acids is about 95 per cent. of the theoretical, and of course none is lost, the remainder being present as neutral oil.

From some quite recent experiments by Nicloux (June, 1904), it appears that the active agent is in reality not an enzyme at all: the fat-splitting enzymes are all soluble in water. Nicloux extracted an insoluble and dry cytoplasm by pounding and grinding castor seeds with water, and centrifugalising to separate from cellulose, etc. The active material so prepared decomposed 500 times its weight of oil in 15 hours. The decomposition is apparently little affected by rise or fall of temperature. No middle layer is formed, and 2 grams of the active substance have the same effect as 100 grams of castor oil seed as used in the German or Connstein process.

An Oxidising Ferment Associated with Gum Acacia

In an important paper in *Journ. Pharm. et de Chimie* [6] 19, 473, 524, E. Bourquelot points out that very many medicaments in frequent use are incompatible with gum acacia on account of the presence with this gum of an oxidising ferment. The ferment, which occurs also in myrrh, frankincense and bdellium, must by oxidation modify to a very serious extent the therapeutic action of many drugs with which it is dispensed. By heating to 100°C. the action of the ferment may be destroyed.

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THE MECHANICS OF HEAVY ELECTRIC TRACTION.

PART II.—ACCELERATION.

By H. F. PARSHALL, M.I.C.E., M.I.E.E., and H. M. HOBART, M.I.E.E.

CONSIDER first an acceleration of one mile per hour per second, or 1·47 feet per second per second. The tractive force required to impart to one ton an acceleration of one mile per hour per second $= \frac{2200}{32 \cdot 2} \times 1 \cdot 47 = 100$ lbs

Useful Rule.—We thus have the useful rule that on a level track, a tractive force of 100 lbs. per ton, in addition to the force required to overcome the tractive resistance, imparts to a train an acceleration of one mile per hour per second. Strictly speaking, one should make an additional allowance for the rotational energy of the wheels and armatures:* this is a matter of from 5 per cent. to 10 per cent. of the whole kinetic energy of the train, depending on the load per axle and construction of the rotating parts. To avoid complicating the question, this additional allowance will not be made, but will subsequently be covered by a margin which will also provide for the energy consumed in air pumps, control apparatus, and, in some cases, train and station lighting and power for auxiliary machinery.

Table III., at the end of this article (p. 432), gives values for the tractive force in pounds per ton required during the accelerating interval, in addition to the tractive force necessary for overcoming friction. In England, rates of acceleration, so far as traction questions are concerned, are almost always expressed either in miles per hour per second, or feet per second per second.

In Fig. 13 six curves of speed and time, distance and time, and speed and distance, are given, for the accelerating interval.

From the speed-time curves in Figs. 13A and 13B, and the distance-time curves in Figs. 13C and 13D, we may obtain, for any given time in seconds from the start, the speed and the distance covered, employing any practicable acceleration. The speed-distance curves of Figs. 13E and 13F are derived directly from the speed-time curves of Figs. 13A and 13B, and the distance-time curves of Figs. 13C and 13D.

Let us now consider the case of a train, to be operated over a straight level track with a stop every mile, at an average speed of thirty miles per hour between stops, for each one-mile section. The train must cover such a one-mile section in two minutes. The rates of acceleration and braking will be assumed to be equal.

According to the conditions of practice in any particular case, the rate of retardation during braking would be taken greater than, equal to, or less than the acceleration. Moreover, in short runs, constant speed between the processes of accelerating and braking is not generally maintained, in electrical operations; the power is often cut off directly the maximum speed is reached, or shortly thereafter, and the friction of the train is thus used to procure a part of the retardation, a less amount of energy being in consequence dissipated at the brake shoes. This naturally leads to correspondingly improved economy. In analysing any particular case where such methods are employed, the values determined upon as regards accelerating, braking and coasting are used in the estimation of the running conditions. But since these details of operation vary enormously in different cases, according to the conditions of service, one would, by endeavouring to take them into consideration in studying the general case, simply lessen the value of the broad conclusions at which one wishes to arrive. Therefore, in the first instance, we shall assume equal rates of acceleration and retardation: for the interval not required for these two operations, we shall assume that the train is run at constant speed. A special study will subsequently be made of the extent of the error in the results consequent upon employing these assumptions. When the study of the general case has been completed, we shall illustrate the analysis of *special* cases, and shall employ the precise rates of acceleration and retardation and the amount of "coasting" suitable for obtaining the best conditions in each case.

For the present purpose it will suffice to briefly illustrate the point involved, by

* "A Consideration of the Inertia of the Rotating Parts of a Train." Storer, Transactions of the American Institute of Electrical Engineers, Vol. xix. (1902), p. 165.

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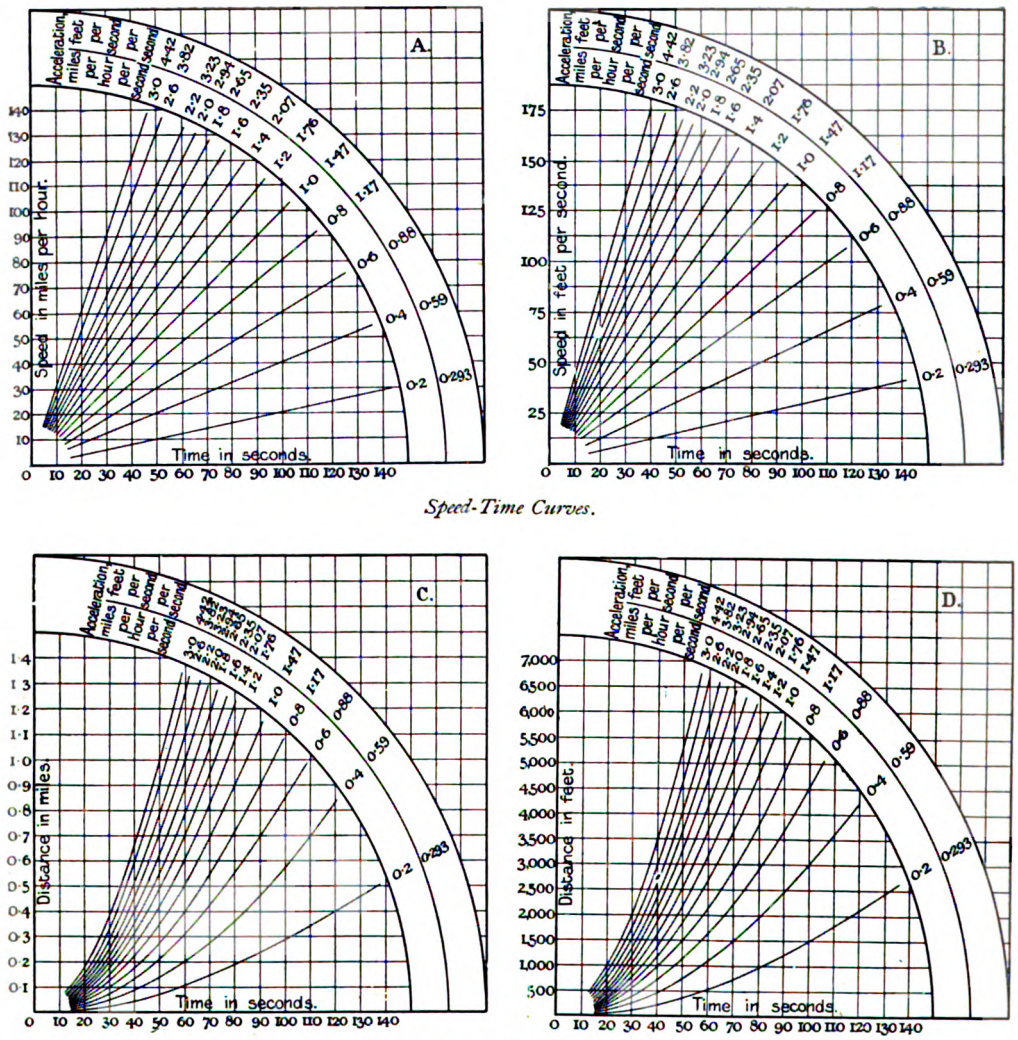

FIG. 13.—SPEED, DISTANCE, AND TIME CURVES FOR VARIOUS ACCELERATIONS.

reference to Figs. 14 and 15, which are taken from Armstrong's paper, entitled "Some Phases of the Rapid Transit Problem," read before the American Institute of Electrical Engineers (1898, Vol. xv., p. 363). In deriving these curves, Mr. Armstrong has made the assumptions set forth below the titles of Figs. 14 and 15. For the purposes of a general survey of the subject, and in view of the conditions as regards rolling stock and permanent way, and the low speeds considered, Mr. Armstrong is not altogether unjustified in taking for the friction the mean value of 15 lbs. per ton, although, as we have already seen from Fig. 1, the friction in lbs. per ton varies through a wide range with variation in the speed.* These two curves (Figs. 14 and 15) are based on an accelerating rate of 0·93 miles per hour per second (a rather low value for

* "It may be said that while there is no material error in assuming constant train resistance for all cases where the speed does not exceed twenty-five miles per hour, yet above these speeds there is a possibility of error which becomes a certainty when the speeds reach forty, fifty or sixty miles, the amount of error increasing with the speed. This matter is now so well understood that a mere mention is sufficient. Very little reasoning will show that the increase of train resistance as a function of the speed cannot be left out of consideration in any computations relating to high-speed service."—Gottshall, Transactions of the American Institute of Electrical Engineers, Vol. xix. (1902), p. 184.

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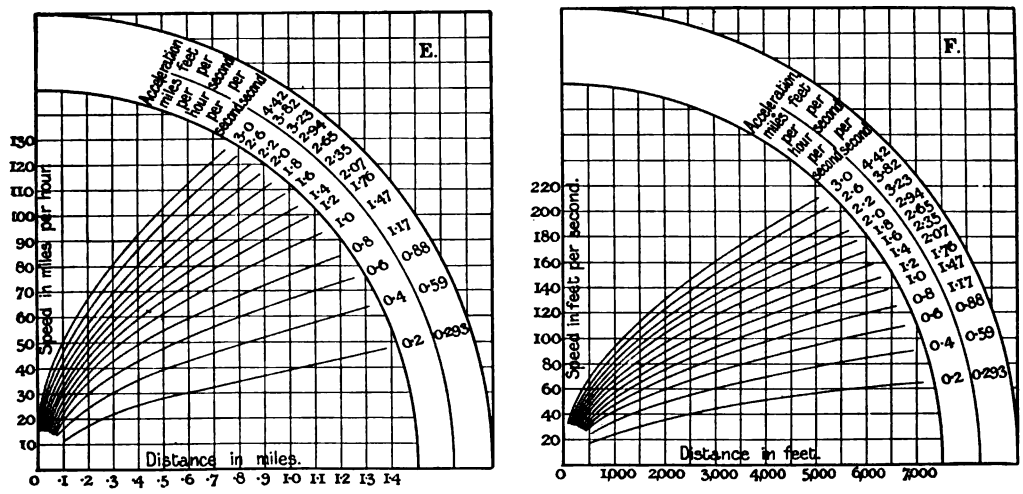

Speed Distance Curves.

FIG. 13 (*continued*).—SPEED, DISTANCE, AND TIME CURVES FOR VARIOUS ACCELERATIONS.

electric traction under the conditions attending one stop per 2,000 feet), and upon a braking effort of 150 lbs. per ton, corresponding to a retardation of 1·6 miles per hour per second. In the curve of Fig. 14 the power is cut off immediately at the end of the accelerating interval (*i.e.*, at the end of 30 seconds, when a speed of 28 miles per hour had been attained, a distance of 600 feet having been covered), and the train coasts for the next 31 seconds (*i.e.*, for the next 1,200 feet), and the brakes are then applied, bringing the train to rest after 75 seconds from the start: the distance of 2,000 feet having been covered at the average speed of 18·2 miles per hour.

In Fig. 15 Mr. Armstrong has illustrated an alternative method (shown in the curve o *b b* 75), of covering the same distance at the same schedule speed of 18·2 miles per hour; sufficient power being kept on, until the brakes are applied, to maintain the constant speed of 25·5 miles per hour attained at the end of 27 seconds of acceleration.

By operating on the curve o *b b* 75, instead of on the curve o *a a* 75, nine per cent. lower

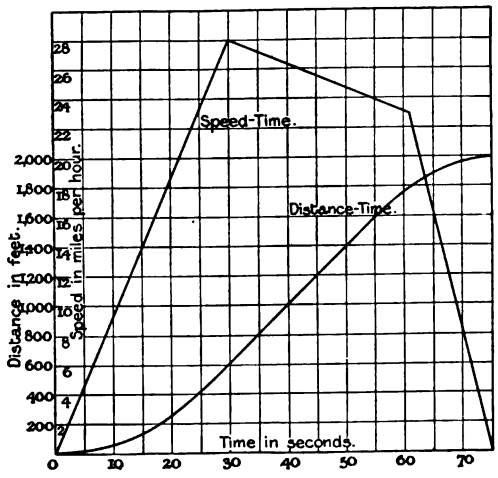

FIG. 14.—SPEED AND DISTANCE CURVES.

Distance, 2,000 feet. Time, 75 seconds. Tractive Effort, 100 lbs. per ton. Friction, 15 lbs. per ton. Braking Effort, 150 lbs. per ton.

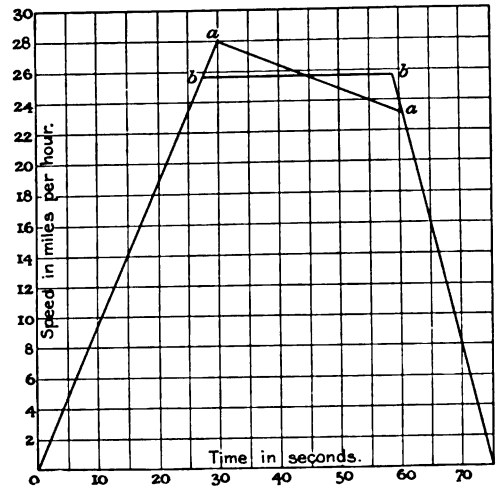

FIG. 15.—SPEED CURVES.

Distance, 2,000 feet. Time, 75 seconds. Friction, 15 lbs. per ton. Braking Effort, 150 lbs. per ton.

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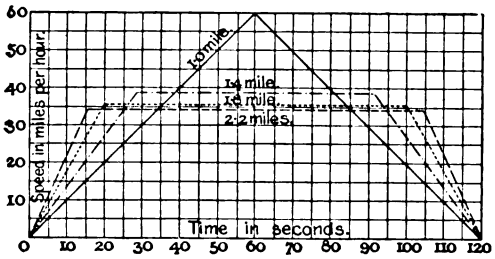
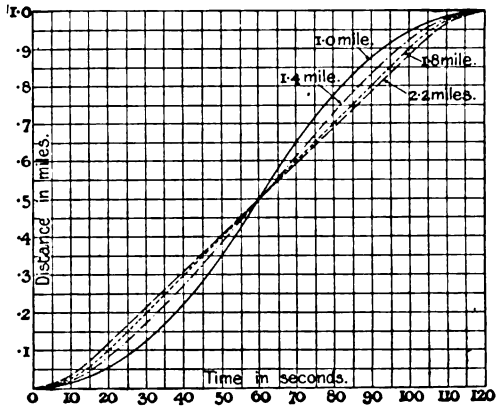
maximum speed, and, as we shall see later, a lower *maximum power* is required for a given average schedule speed; but, as we shall also see later, this is at the cost of nine per cent. more *total energy* consumed during the run. The relative merits of these two methods, as also that of "acceleration on the motor curve," cannot well be considered at any length until the subject of tractive force and energy curves is taken up. It may here be briefly stated that cycles approaching that illustrated in Fig. 14 and in curve o *aa* 75 of Fig. 15 are more suitable for frequent stop service at a high average speed; but that the longer the run between stops, or the lower the average speed, the more does the cycle employed in actual service resemble that illustrated by the diagram o *bb* 75 of Fig. 15. The error introduced by adopting the latter type of diagram throughout this preliminary study is the greater, the shorter the run between stops and the higher the average speed; but the error is on the safe side, and immense advantage is gained in obtaining a preliminary broad view of the limiting factors, to free this necessarily complex investigation from as many subsidiary considerations as practicable.

Returning to the general case of a train to be operated over a straight level track, with a stop every mile and at an average speed of 30 miles per hour for each one-mile section (assuming equal rates of acceleration and braking), it is evident that the very lowest rate of acceleration must enable the train, during an accelerating interval of 60 seconds, to cover a distance of 0·50 mile. Fig. 13C shows us that the corresponding rate of acceleration is one mile per hour per second (1·47 feet per second per second). We may, if we choose, find from Fig. 13A that the speed at the end of 60 seconds is 60 miles per hour (reading off the speed from the intersection of the ordinate at 60 seconds, with the line of reference for an acceleration of one mile per hour per second), although this is obvious without consulting a diagram.

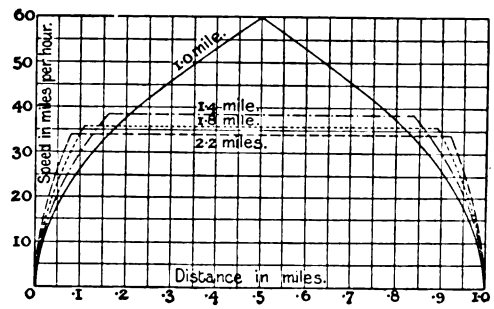
The speed-time curve would thus be the one-mile curve of Fig. 16A, the accelerating half being transferred directly from Fig. 13A, and the braking half being merely the reverse of this curve. The corresponding distance-time curve is given in Fig. 16B; the accelerating half is transferred directly from Fig. 13C. Fig. 16C is transferred directly from Fig. 13E for an acceleration of one mile per hour per second, and gives the speeds as ordinates in terms of distances as abscissæ. These are the three characteristic curves for the case of a train



A—*Speed-Time Curves for accelerations of* 1·0, 1·4, 1·8, *and* 2·2 *miles per hour per second.*



B—*Distance-Time Curves for same accelerations.*



C- *Speed-Distance Curves for same accelerations.*

FIG. 16.

SPEED, DISTANCE, AND TIME CURVES FOR A ONE-MILE RUN AT A MEAN SPEED OF 30 MILES PER HOUR. SCHEDULE TIME, 2 MINUTES.

travelling over a one-mile section at an average speed of 30 miles per hour, for the minimum rate of acceleration and braking, permissible for this schedule.

Let us next take an acceleration of 1·4 miles per hour per second (2·07 feet per second per second), and let it be assumed that the braking is at an equal rate. Let x = duration of accelerating interval in seconds; then $120 - 2x$ = duration of constant speed interval. Space in feet covered during acceleration = $0·5 \times 2·07 \times x^2$. Speed in feet per second attained at end of accele-

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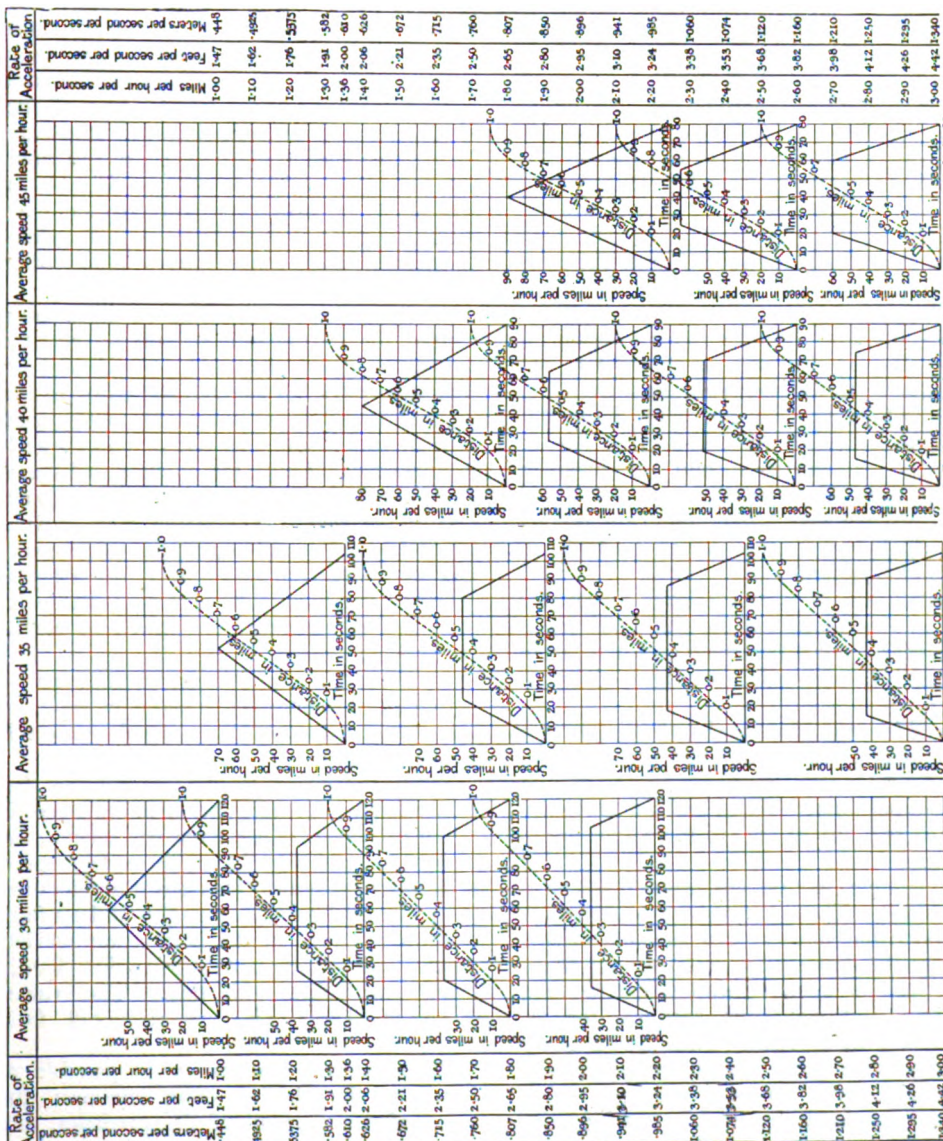
Rate of Acceleration.
Average speed 30 miles per hour.
Average speed 35 miles per hour.
Average speed 40 miles per hour.
Average speed 45 miles per hour.
Miles per hour per second.
Feet per second per second.
Meters per second per second.
Speed in miles per hour.
Time in seconds.
Distance in miles.

FIG. 17.—SPEED-TIME AND DISTANCE-TIME CURVES FOR VARIOUS ACCELERATIONS AND AVERAGE SPEEDS: ONE MILE RUN.

The acceleration for any given curve will be found opposite its base line, in the tables at the sides of the figure. The speed-time curves are drawn thus ——, *the distance-time curves thus* – – – – –

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rating interval $= 2 \cdot 07 \times x$. Distance in feet covered at constant speed $= 2 \cdot 07 \times x \times (120 - 2x)$. Distance in feet covered during braking $= 0 \cdot 5 \times 2 \cdot 07 \times x^2$. Total distance = 5,280 feet.

From these values we readily derive the following equation :—

$$2 \cdot 07\, x^2 - 248\, x + 5280 = 0$$
$$x^2 - 120\, x + 2540 = 0$$
$$\therefore x^2 - 120\, x + 3600 = 1060$$
$$x - 60 = -32 \cdot 5$$
$$x = 27 \cdot 5 \text{ seconds.}$$

From Fig. 13C we see that after 27·5 seconds of acceleration at a rate of 1·4 miles per hour per second, a distance of 0·15 mile will have been covered; and from Fig. 13A it is seen that a speed of 38·8 miles per hour will have been attained. During the succeeding 65 seconds the speed will be constant at this value, and a distance of 0·70 mile will be covered at constant speed. During the remaining 27·5 seconds the brakes will be so applied as to produce a retardation of 1·4 miles per hour per second, and the train will arrive at the end of the mile section in just 120 seconds.

Generally, one will not trouble to calculate the accelerating interval as above, but will determine it, by one or two trials, from the curves of Figs. 13C and 13A. The three characteristic curves for this accelerating rate of 1·4 miles per hour per second are shown in the 1·4 mile curves of Fig. 16; and it will be readily perceived that they are merely made up by combining curves available in Figs. 13C, 13A, and 13E.

Similar sets of characteristic curves for other accelerations, but for the same mean speed of 30 miles per hour and the same distance of one mile, are also given in Fig. 16.

For this case of a level one-mile section corresponding charts of curves have been worked out for average speeds of 35, 40, and 45 miles per hour. These are not all reproduced here; but in Fig. 17 the whole group of *speed-time* and *distance-time* curves for this level one-mile section are reproduced on a small scale. These curves are too small to be serviceable, further than as a scheme for charts to be drawn to a scale several times larger, such as we have worked out for one, two, four and eight-mile sections, for reference use in practice. Such charts show the conditions and limitations in a way unattainable with mere formulæ. After having determined the suitable running conditions for a given case, by reference to charts, it often becomes expedient to resort to formulæ, but this is largely a matter of individual preference. In the initial stages of an investigation, however, the use of charts of this kind is far more instructive than the use of formulæ, and it is a matter for regret that such charts on a small scale cannot be made sufficiently legible for use. In a subsequent re-publication of an amplification of these articles as a treatise on "Electric Railway Engineering," it is the purpose of the writers to select as large a page as practicable, and to arrange an exhaustive series of these charts in a chapter devoted to the purpose. This series of charts will embrace, not only an extensive collection of S.T.D. curves, but also tractive force curves and curves of total energy at the train wheels. We have already prepared these curves on a large scale for runs of one, two, four, and eight miles between stops, and for average speeds of from 30 to 100 miles per hour, according to the conditions. In this series of articles it will only be practicable to give a few sections of such groups of curves, and some curves representing deductions made from the series.

The four curves of Fig. 18 have been plotted, for this one-mile section, to show the maximum speeds required for different accelerating rates, for average speeds of 30, 35, 40, and 45 miles per hour. From the commercial standpoint, the last of these speeds is impracticably high for so short a distance as one mile between stops. The minimum rate of acceleration possible with such a schedule is 2·25 miles per hour per second; and the maximum speed then necessary is 90 miles per hour. Nevertheless, its inclusion in the investigation serves to define the problem.

In Fig. 19, a curve is drawn showing the minimum accelerations possible in order to accomplish given average speeds over this one-mile section.

From the curve of Fig. 19 we see that with one stop per mile and a limiting acceleration of one mile per hour per second, the highest theoretically obtainable average speed is 30 miles per hour. This rate of acceleration (one mile per hour per second) would conform to the conditions of the best steam service, much higher rates of acceleration hardly being practicable with this. The values given in Table IV. are deducted from Fig. 19.

With electric traction it is possible to distribute the driving effort amongst the axles of some or all of the carriages, and accelerating rates above two miles per hour

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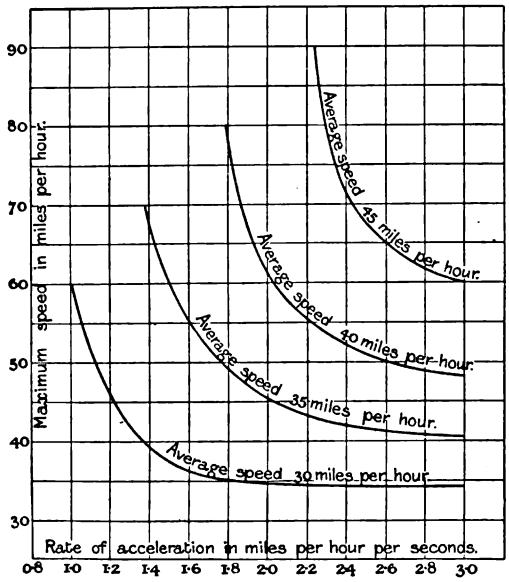
Maximum speed in miles per hour.
Average speed 45 miles per hour.
Average speed 40 miles per hour.
Average speed 35 miles per hour.
Average speed 30 miles per hour.
Rate of acceleration in miles per hour per seconds.

FIG. 18.—MAXIMUM SPEEDS FOR A ONE-MILE SECTION, FOR VARIOUS ACCELERATIONS AND AVERAGE SPEEDS.

TABLE IV.

Limiting Rate of Acceleration in miles per hour per second.	Corresponding Average Schedule Speed obtainable with one stop per mile.
0·6	23
0·8	27
1·0	30
1·2	33
1·4	36
1·6	38
1·8	40
2·0	42
2·2	44
2·4	46
2·6	48
2·8	50
3·0	52

per second become practicable; hence—aside from the question of the instantaneous loads imposed upon the system, and the weight of the electrical equipment required to be carried on the train (both of which limitations will be discussed later)*—schedule speeds of over 40 miles per hour would be theoretically practicable with one stop per mile. Indeed, tests have shown as high an acceleration as

* These limitations suffice to prevent the practicability of schedule speeds of over 35 miles per hour with one stop per mile, and even so high a schedule speed with one stop per mile is of doubtful practicability from the commercial standpoint.

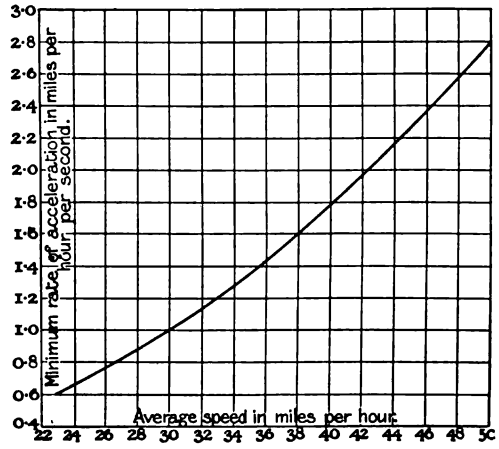

FIG. 19.—CURVE OF MINIMUM ACCELERATIONS FOR GIVEN AVERAGE SPEEDS OVER A ONE-MILE SECTION.

three miles per hour per second to have been attained by electric traction. A curve is given in Fig. 20 of a run made over a 5,360 feet section, with a 71·5-ton electric train of motor cars without trailers. The average rate of acceleration during the first five seconds is seen to be nearly three miles per hour per second. This acceleration was, however, not maintained, and the retardation was at a lesser rate; and although the maximum speed was 47 miles per hour, the average speed was but 35 miles per hour. This was a very high average speed for so short a section, and it would rarely be practicable to attain it; for, as we shall subsequently show, the amount of power required during acceleration is

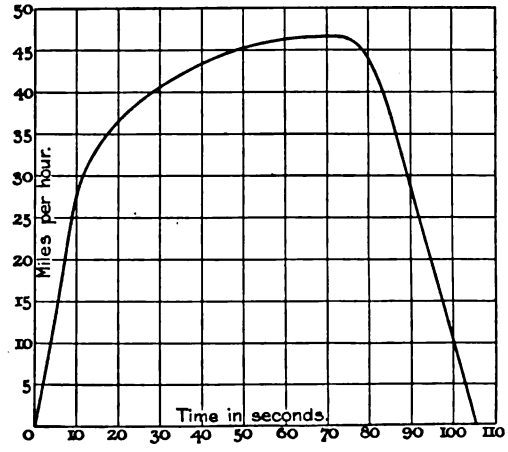

FIG. 20.—SPEED-TIME CURVE FOR A 71·5 TON ELECTRIC TRAIN OF MOTOR CARS (NO TRAILERS).

5,360 *feet run. Power on for* 4,080 *feet. Watt-hours per ton-mile* = 129.—*From the Trans. Amer. Inst. Elect. Engnrs.*, Vol. xix., p. 844.

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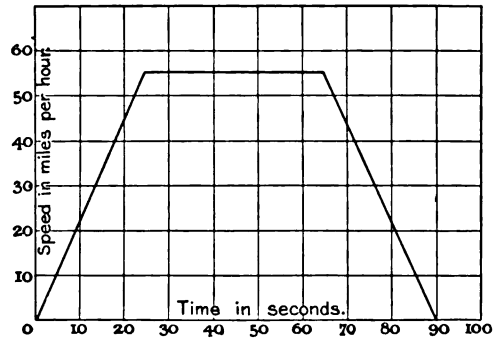

FIG. 21.—SPEED-TIME CURVE, FOR A CONSTANT ACCELERATION OF 2·2 MILES PER HOUR PER SECOND; MEAN SPEED, 40 MILES PER HOUR.

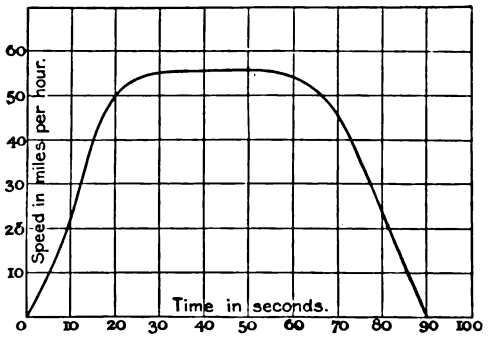

FIG. 22.—SPEED-TIME CURVE FOR A MEAN ACCELERATION OF 2·2 MILES PER HOUR PER SECOND; MEAN SPEED, 40 MILES PER HOUR.

excessive, and the weight of the electrical equipment requiring to be carried on the train is enormous, if the service is to be continuously maintained without undue heating. It is important to note that this is the case; although, could the three miles per hour per second accelerating rate be maintained, we see from Table IV. that a 50 per cent. higher average speed (52 miles per hour) would be practicable, without exceeding any limitations introduced up to this point of the investigation.

Turning back to Fig. 17, the general form of the two upper curves (*i.e.*, those for average speeds of 45 and 40 miles per hour) affords evidence, quite aside from the question of power and weight of equipment, of the commercial impracticability of maintaining an average speed of over 35 miles per hour with one stop per mile.

For the purposes of this general investigation, the diagrams are drawn for a constant acceleration throughout the accelerating interval. In practice, however, the acceleration is itself variable, being at first gradually increased to above the average rate and then decreased until constant speed is reached. By such variation of the acceleration, it is practicable to employ a high average acceleration without undue strain upon the rolling stock and permanent way, and without much discomfort to passengers. This is the more necessary the higher the average acceleration. Thus the curve of Fig. 21, reproduced above, would in reality be replaced by a curve more like that in Fig. 22.

TABLE III.—TRACTIVE FORCE AND ACCELERATING RATE.

Acceleration expressed in meters per second per second	0·112	0·224	0·336	0·447	0·560	0·671	0·784	0·895	1·00	1·12	1·225	1·335
Acceleration expressed in kilometers per hour per second	0·402	0·805	1·21	1·61	2·01	2·42	2·82	3·22	3·62	4·02	4·42	4·83
Acceleration expressed in miles per hour per second	0·25	0·50	0·75	1·00	1·25	1·50	1·75	2·00	2·25	2·5	2·75	3·0
Acceleration expressed in feet per minute per second	22·0	44·0	66·0	88·0	110	132	154	176	198	220	242	264
Acceleration expressed in feet per second per second	0·366	0·733	1·10	1·47	1·83	2·20	2·56	2·93	3·30	3·67	4·04	4·42
Tractive force in pounds per ton	25·0	50·0	75·0	100	125	150	175	200	225	250	275	300
Tractive force in kilograms per ton	11·3	22·7	34·0	45·5	56·7	68·0	79·5	90·7	102·0	114·0	125·0	136·0

(*To be continued.*)

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ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES.

PART V.—ELECTRIC-FURNACE PRODUCTS.

By JOHN B. C. KERSHAW, F.I.C.

FIG. 1.—VOLTA CARBIDE WORKS, VERNIER, NEAR GENEVA.

Introduction.

IN the four previous articles of this series (see TECHNICS for March, April, June, and August, 1904), the author has described and illustrated the use of the electric current for the production of aluminium, copper, iron and steel, lead, nickel, tin and zinc, and for the manufacture of various chemicals obtained by the decomposition of sodium or potassium chloride, known in the trade as "heavy chemicals." The use and development of these electro-chemical and electro-metallurgical processes has been followed in some detail, and it has been proved that in many cases the industries based upon them are of striking growth and of increasing importance. In the concluding articles of this series, the author proposes to deal briefly with the remaining chemical and metallurgical processes in which electricity has been used upon an industrial scale of operations, commencing with the large number of applications in which the electric current is employed solely as a heating agent, the high temperature of the electric furnace being then utilised to produce metallurgical or chemical reactions and products unobtainable by the ordinary methods of heating.

I.—ELECTRIC FURNACE PRODUCTS.

Electricity may be employed either as direct or alternating current, for arc or resistance-heating in the electric furnace; and furnaces of each type are now being employed upon an industrial scale in connection with new manufactures. As a general rule, the electricity utilised is generated very cheaply from water-power, and is employed as alternating current in furnaces of various design. The complete history of the development of the electric furnace and of its application to metallurgical and chemical reactions would demand a series of articles in itself, and readers interested in this aspect of the subject may be referred to the standard works by Borchers, Moissan, and Minet upon it. In the present article limits of space will only permit a brief description of the applications of this method of heating to the manufacture of certain products, and no attempt can be made to deal historically with these manufactures.

Calcium Carbide.

When lime and charcoal are heated together at a temperature of over 3,000° C., a combination of calcium and carbon is obtained, which is represented chemically by the formula CaC_2. This substance when treated with water is decomposed, and one obtains from it a gas known as acetylene (chemical symbol C_2H_2) of very high illuminating power. Calcium carbide and its derivative acetylene have been known to chemists since the middle years of the nineteenth century:

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but not until Wilson in America, and Moissan in France, discovered that calcium carbide could be easily produced in the electric furnace by heating together lime and charcoal, did the product become of commercial importance. This discovery was, however, the foundation of a new industry, and since 1894 the manufacture of calcium carbide has developed until it has become the largest and most important of the electro-metallurgical industries. Unfortunately for those who have found the money to promote this application of the electric current, exaggerated statements as to the cheapness and advantages of acetylene as an illuminant and possible rival of coal-gas led to much unwise speculation in the new industry in the years 1898, 1899, and 1900. Many of the carbide factories erected in these three years in France, Italy, and Switzerland, in connection with water-power developments, have been compelled to shut down, or to divert their power into other branches of electro-metallurgical manufacture.

Litigation in connection with patent claims in the various countries, and price-cutting due to over-production, have also hampered the smooth development of the calcium carbide industry; while explosions due to the erection and use of faulty acetylene generators have shaken the confidence of many people in the safety and value of acetylene as a lighting agent. However, the experience of the last ten years has taught those connected with the calcium carbide and acetylene industries many things they much required to learn, and these industries have probably now passed that critical and dangerous stage of development in which "booming" for company-promotion purposes is the order of the day. Every country in Europe now possesses one or more carbide works: acetylene gas installations are to be found in large numbers even in our own conservative country districts where neither coal gas nor electricity has yet been adopted for lighting purposes. It is in such districts that acetylene as an illuminant has most scope, for in large towns it is neither so cheap nor so generally convenient as its two rivals—gas and electricity.

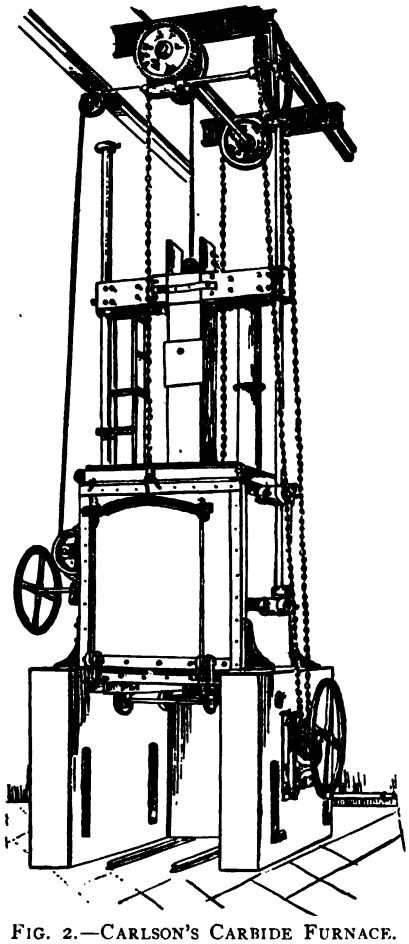

FIG. 2.—CARLSON'S CARBIDE FURNACE.

As regards the total power utilised in the calcium carbide industry at the present time, and the output of this product, no very trustworthy figures can be given; but the present writer, in an article on the industry published in the issue of the *Mineral Industry Annual* for 1900, gave a list of 93 places where carbide factories had been erected or were in course of erection. Many of these are now stopped, but it is probable that more than one-half of them are still in operation. Taking the moderate average of 1,000 h.p. for the power utilised in each of these works, and an output of 5 kgs. per k.w. day of 24 hours (equal to 1·6 tons per k.w. year, or 1·2 tons per e.h.p. year), it may be calculated that, at the present time, about 50,000 h.p. is being devoted to this manufacture, and that over 60,000 tons of carbide are being annually produced in the carbide works of Europe and America.

Fig. 1, at the head of this article, shows the Volta Carbide Works at Vernier, near Geneva, where 7,000 h.p. is available. Fig. 2 shows the Carlson type of furnace for carbide manufacture, patented by the "Gold u. Silber Anstalt" of Frankfort; and Fig. 3 shows a central acetylene gas installation at Oliva, near Dantzig, in Germany. It is in Germany that the largest number of central acetylene gas installations have been erected, the coal gas industry being not nearly so widely extended as in the United Kingdom, and the conditions being therefore more favourable to the use of acetylene as a lighting agent.

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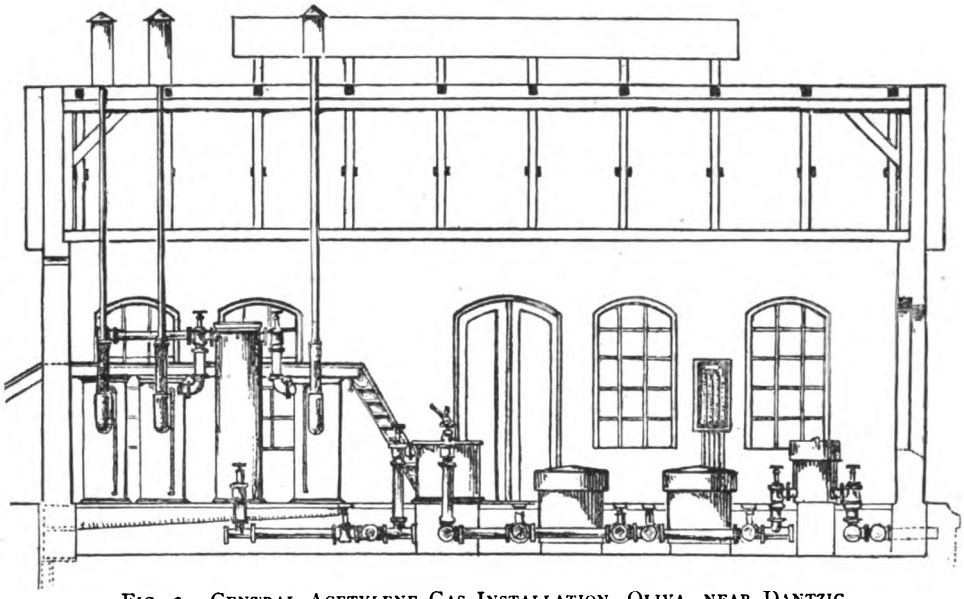

FIG. 3.—CENTRAL ACETYLENE GAS INSTALLATION, OLIVA, NEAR DANTZIG.

Carborundum.

This compound (chemical formula SiC) is a carbide of silicon, and was first produced in quantity at Niagara Falls by an American inventor, E. G. Acheson, the founder of more than one successful electro-metallurgical industry in the United States. Carbide of silicon was accidentally produced by Acheson and by Edison, while attempting to make artificial diamonds by aid of the electric furnace. As the product was found to be harder than emery, its value and importance were at once recognised, and its manufacture, as a substitute for emery and corrundum, was at once commenced. The method of manufacture is simple—a mixture of coke, sand, and sawdust is heated in an electric furnace of the resistance type, to a temperature of nearly 4,000° C., and, after cooling, the fused mass is broken up, ground in special mills, and the powder made up into a great variety of forms for grinding purposes. Starting with comparatively small furnaces, Acheson has gradually increased their size, until furnaces 22 feet long and 8 feet in diameter, with a capacity of 2,000 h.p., have been reached. The terminals for this size of furnace consist of 50 carbon

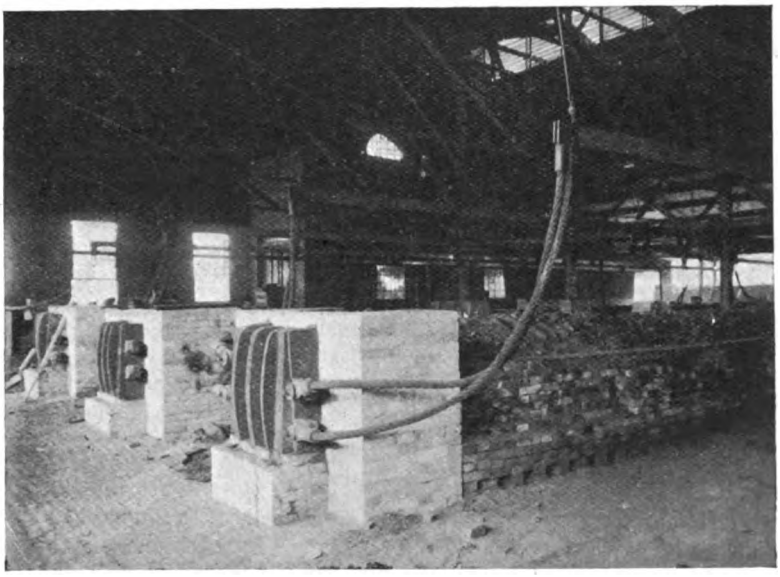

FIG. 4.—ACHESON TYPE OF FURNACE FOR THE PRODUCTION OF CARBORUNDUM AND ARTIFICIAL GRAPHITE.

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blocks, each 4 inches square by 32 inches in length; flat copper strips are inserted between these blocks to obtain electrical contact. The general external appearance of such a furnace is shown in Fig. 4, which represents one of the furnaces used for the manufacture of artificial graphite at Niagara Falls. Such a furnace will produce 10 tons of carborundum in 36 hours; the manufacture has now reached such dimensions that 5,000 h.p. is utilised at the Niagara Falls works, and in 1903, 2,380 short tons of carborundum, valued at $472,000, were produced. Smaller plants for manufacturing this product have been erected by the Acheson Carborundum Company (simply to protect their patent rights) in Germany, Austria, and other European countries having such a clause in their patent laws; but the chief centre of manufacture remains in the United States.

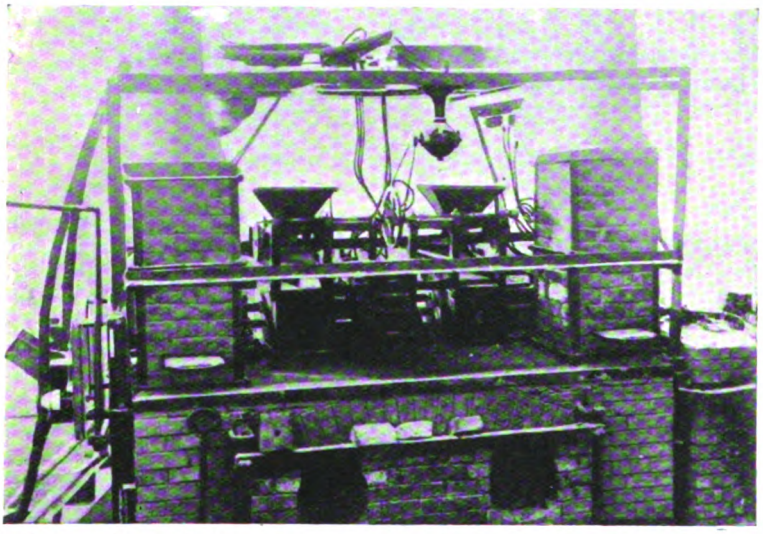

FIG. 5.—BECKER'S ELECTRICALLY-HEATED GLASS FURNACE (REAR VIEW).

Carborundum, in the form of wheels, tools, and paper, has been widely adopted as a grinding agent in the metal and other industries; and the new industry founded by Acheson at Niagara Falls is to all appearances a healthy and progressive one.

Artificial Graphite.

It had long been known that amorphous carbon can be converted into graphite by treatment in the electric furnace, but it remained for E. G. Acheson, the discoverer and patentee of carborundum, to found a successful industrial process for the manufacture of graphite upon this method of treatment. When experimenting with the action of high furnace temperatures upon carborundum, Acheson found that it is decomposed into its constituents, silicon and carbon, at a temperature approaching 4,000°C., and that the carbon separates out in the form of graphite. Further experiments proved that most carbides suffer this decomposition, and that the presence of only a small amount of the carbide-forming base element is required to convert the whole of the carbon present into graphite. It is the discovery of the latter fact that is the main feature of Acheson's work upon this subject, which has enabled the process to become a remarkable industrial success. Anthracite coal, containing a fairly high percentage of ash, is employed as raw material of the process, and this is simply heated in the resistance type of electric furnace shown in Fig. 4, using a core of carbon rods to carry the current right through the centre of the mass. A current equivalent to 1,000 h.p. is conducted through the furnace, and the heating is continued until the silicon and iron carbides, formed by the combination of the anthracite with the silicon and iron of the ash, are decomposed again, and the silicon driven off as a gas to the outside of the mass, where it is deposited in the solid form as SiO_2. Graphite then remains in the furnace.

The works of the "International Acheson Graphite Company," at Niagara Falls, now utilise 1,000 h.p. in this manufacture, and the plant is undergoing extensions which, when completed, will absorb another 2,000 h.p. The Acheson graphite finds a wide field of utilisation in the electro-chemical industries, since it forms a most useful and valuable electrode material, being easily machined and turned in the lathe to any desired form. Its resistance to oxidation, when used as anode material, is far higher than that of

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gas-coke, or any other forms of carbon. The output of the Niagara Works in 1903 was equal to 2,082,000 lbs.; small subsidiary plants are also operated by the parent company at La Bathie, in France, and at Benetek, in Hungary, for the purpose of protecting the patent rights in these two countries.

Glass.

Attempts have recently been made to apply the electric furnace to glass manufacture, the idea being that if the trials are successful, this industry could be started in countries which possess very cheap water-power and supplies of the raw materials (sand, lime and soda), but no coal. It is yet too early to say that the electric glass furnace is a success; but Figs. 5 and 6 show two working views of a furnace designed by Becker, a German engineer, who, with another German named Voelcker, is acting as pioneer in this industry. The Becker and Voelcker furnaces were first operated at Cologne, and they are now receiving trial upon an industrial scale at Mattrei, in the Tyrol, and at Plettenberg, in Westphalia. Readers especially interested in this subject are referred to the issue of the *Electrical Review* (New York) for November 21st, 1903, for a fuller account of these trials, and for an estimate of the future prospects of this application of the electric furnace.

It may be pointed out here that there is no question of the electric furnace supplanting the ordinary gas-fired regenerative glass furnace (which is wonderfully efficient) in districts where cheap coal is obtainable, the competition of electricity as a heating agent for glass manufacture in such localities being impossible. The use of the electric glass furnace, if the difficulties of its application to this purpose are surmounted, will therefore be confined to countries like Norway and Switzerland, where fuel is scarce and water-power abounds.

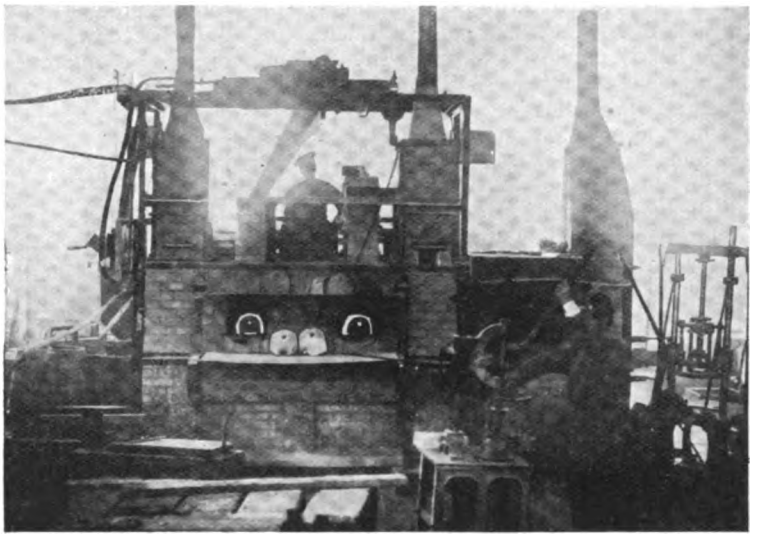

FIG. 6.—BECKER'S GLASS FURNACE (FRONT VIEW).

Ferro-Chrome, Ferro-Silicon, and other Alloys of Iron.

The production of ferro-chrome, ferro-silicon, and of many other special alloys of iron by aid of the electric furnace, has now become a widely extended and successful branch of electro-metallurgy, and nearly every country in Europe is represented in these new industries. Of these manufactures that of *Ferro-Silicon* is probably the largest, the number of works producing this alloy by electric furnace methods in Europe being now between fifteen and twenty.

The method of manufacture is simple, scrap-iron or scrap-steel being simply heated with pure quartz in a resistance type of furnace, until chemical combination between the two occurs. The product contains up to 25 per cent. Si., and a k.w. hour is said to yield 0·20 kg. of ferro-silicon. The advantage of this method of manufacture is that the product contains very little phosphorus, rarely above 0·02 per cent. A 4,000 h.p. plant can turn out 20 tons of 30 per cent. ferro-silicon per day. The industry has developed very largely in France, and that country is now exporting large quantities of ferro-silicon to America. The product is employed for adding to steel before casting, the silicon combining with the oxygen present as FeO, and improving the fluidity and purity of the casting: it has been very extensively used for this purpose, and one of the results has been over-production of the product in Europe. A sales-bureau has therefore been

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organised to regulate production and price. Lately, silicon-carbide (carborundum) has been used in place of ferro-silicon by steel-founders, and the consumption of the latter has suffered in consequence. Two explosions of ferro-silicon at Liverpool, in 1903, have proved the compound to be unstable and dangerous under certain conditions of temperature and storage.

Ferro-chrome is another electric-furnace product which is being largely employed in the iron and steel industries. Willson, the American discoverer of calcium carbide, is manufacturing this alloy at Holcombe Rock, U.S.A., 150 tons per month being produced there in a modified form of the Willson carbide furnace. Chrome ore from Asia Minor is reported to be in use as raw material, and an alternating current equivalent to 3,000 h.p. is employed to smelt this ore on the hearth of the furnaces. The ferro-chrome produced contains 70 per cent. Cr.; the alloy is largely used by the Carnegie and Bethlehem Steel Companies in the manufacture of armour plates. An alloy containing 66 per cent. to 70 per cent. Cr. and less than 1 per cent. C., is stated to be the best for use in steel manufacture, since it melts rapidly. In Europe, ferro-chrome is produced at Froges, France, by the *Société Electro-metallurgique Française*, and by the Goldschmidt process at Essen, in Germany. Chrome-steel is also being directly made by the Héroult process at La Praz, France (see Article IV.).

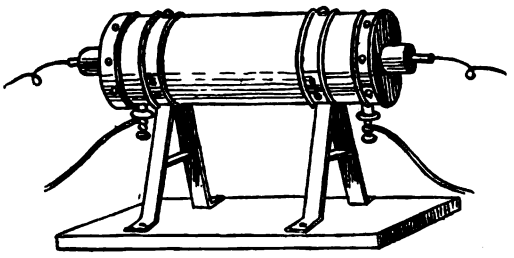

FIG. 7.—ELECTRICALLY-HEATED LABORATORY FURNACE.

Other electric-furnace products of this type are *ferro-titanium*, *ferro-manganese*, and *silicon-copper*. The first of these is being produced at Niagara Falls, by A. G. Rossi; scrap-iron, titaniferous iron ore, and aluminium are employed as the raw materials of the process. A modified form of this process consists in smelting titaniferous iron ore with a limited supply of coke, and then utilising the slag (which contains all the titanium) for the manufacture of ferro-titanium. Ferro-manganese is being manufactured at Orlu, in the French Pyrenees, by the Simon process. In principle this process resembles the Héroult aluminium process: manganese dioxide, containing iron as an impurity, is dissolved in a bath of molten calcium fluoride, and the mixture is electrolysed at a temperature of 1,300° C. The reduction which takes place is partly electrolytic and partly chemical. The product contains 84 per cent. Mn., 8 per cent. Fe., and 7 per cent. C.

Silicon-copper is a new product, manufactured by the Cowles Electric Smelting Co., at their Lockport Works, New Jersey. This product is being employed for adding to copper before casting; the silicon combines with and carries off the oxygen from the CuO present in the molten mass. The principle of this use of silicon copper is of course similar to that governing the use of aluminium and of ferro-silicon in the iron and steel foundry.

Siloxicon.—This is another of the electric-furnace products discovered by Acheson. It is produced by heating together, in the electric furnace, a mixture of ground coke, sand, and sawdust, to a temperature of between 2,500° C. and 2,750° C. A product containing silicon, carbon, and oxygen, represented by the chemical formula Si_2C_2O, is obtained. This material is highly infusible, and it is being sold as a lining for electric and other furnaces. It is self-binding and, when moistened with water, can be moulded to any desired shape. Siloxicon is also insoluble in metals, and is inert towards both acid and basic slags. Mixed with 25 per cent. of clay, it can be made into crucibles superior to those of clay, or of clay and graphite. At temperatures approaching 4,000° C. siloxicon is decomposed into its elements, silicon carbide being first produced, and then silicon and graphite. 130,000 lbs. of siloxicon have been produced so far by Acheson at Niagara Falls.

Electric Furnaces for use in the Chemical Laboratory.

The electric resistance furnace has been modified by Heraeus and others to render it suitable for heating purposes in the chemical laboratory: Fig. 7 is a view of such a laboratory furnace designed for heating tubes to any desired temperature from 500° C. to 1,800° C.

A porcelain inner tube is wrapped round with fine platinum wire or foil, and the ter-

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minals of this spiral are then connected to the source of current supply. An insulating tube of asbestos or other material is employed to contain the inner porcelain tube with its spiral resistance, and the whole is contained in a large sheet-iron drum, closed at the ends, and filled with powdered glass or quartz.

The temperature in furnaces of this type is easily controlled by varying the external resistance, and the only drawback to their use is the difficulty of maintaining the platinum resistance spiral in good condition. Temperatures of 1,700° C. can be attained, and maintained in these furnaces for any length of time, and in a modified form they can also be employed for heating crucibles.

(To be continued.)

THE "DRIFT" OF PROJECTILES.

By F. W. LANCHESTER.

THE cause of the deflection of a rifle bullet or projectile in its flight, to the right or left of the line of sight according to the direction of the rifling, is due to gyroscopic action.* One of the conditions necessary to the proper flight of a rifle bullet is that its mass-centre (centre of gravity) shall not be too far forward; to be exact, it must be well behind the centre of wind pressure when the bullet has a slightly oblique motion. This is, in effect, how all bullets and projectiles for rifled guns are made. As a result, if the projectile were not spinning its equilibrium would be unstable, and it would tumble over in its flight.

A parallel may be drawn between the rifle bullet and the ordinary spinning top, of which also the equilibrium is unstable in the absence of rotation. Just as the spinning top acquires stability by rotation, so does the projectile.

This familiar parallel enables one to accept at once the well-known fact that the axis of a projectile lies at all points of the flight in the direction of the trajectory; for, if we suppose this axis to maintain its original direction, so that after a time it becomes oblique to the direction of flight, we see that its condition is that of a spinning top, resting permanently in an inclined position without precession, which is a condition we know to be impossible.

If we suppose a bullet to be launched obliquely (as when the muzzle of the gun is in a strong wind) its subsequent career is of corkscrew form, owing to "precession" such as shown by a spinning top having an inclined axis; but if the change of condition is slow, such as when the course of the bullet is changed by gravity, the axis simply adapts itself to the new direction.

I have so far dealt with the problem by analogy rather than by the more rigid method, in order to avoid becoming tedious and taking too much space; I propose now to take "tangent-to-trajectory" flight of the projectile as an established hypothesis (it is

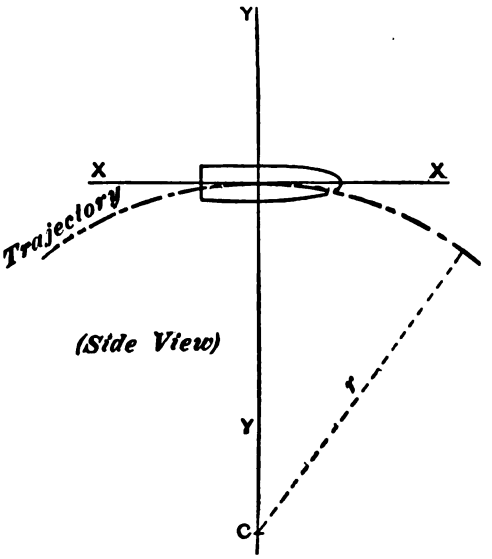

FIG. 1.—SIDE VIEW OF PROJECTILE AND ITS TRAJECTORY.

* For discussions of gyroscopic actions, see "The Mechanics of the Gyroscope," by Dr. T. Preston (TECHNICS, No. 7, p. 47), and another article under the same title by Mr. E. Edser (TECHNICS, No. 9, p. 225).

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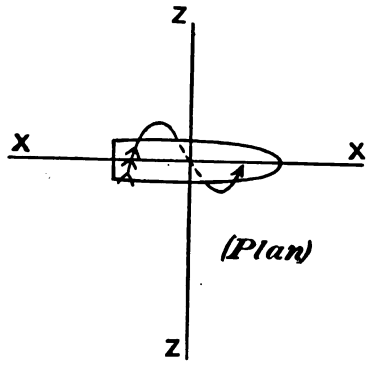

FIG. 2.—PLAN OF PROJECTILE.

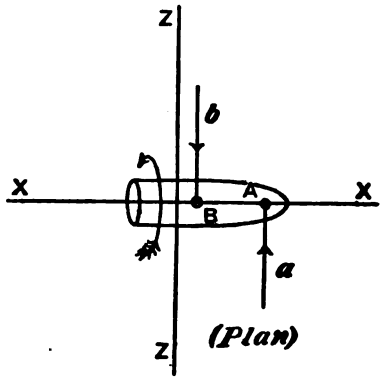

FIG. 3.—TO ILLUSTRATE CHANGE OF ASPECT OF PROJECTILE.

generally admitted as an experimental fact), and show how the drift follows as an immediate consequence.

Fig. 1 represents a projectile and trajectory in side elevation.

Fig. 2 gives same in plan.

Fig. 3 shows the change of aspect in plan after a brief interval of time.

Let r be the instantaneous radius of the trajectory, then the projectile may be regarded as moving for the moment geometrically about the centre C (Fig. 1).

Taking three co-ordinate axes as "X" in the line of flight, "Y" vertical, and "Z" at right angles to both, we see that in plan Fig. 2, there is no angular momentum about the axis of "Y"; but in plan Fig. 3, a small increment of time later, we find, due to the change of "aspect," the presence of angular momentum in a counter-clockwise direction when viewed from above (the rifling is taken as left-handed).

Now, we know from first principles this signifies a "torque" or "couple" acting on the bullet in the direction of the angular momentum received; and we know that from the conditions of the problem, the elements of this couple can be resolved as a lateral wind pressure acting at a point A (Fig. 4), and an equal and opposite inertia resistance at B (the centre of mass).

This signifies that the condition of flight necessary to the axis "following the trajectory" is that this axis is slightly oblique laterally, as indicated in Fig. 4. It is to this obliquity that the "drift" is due.

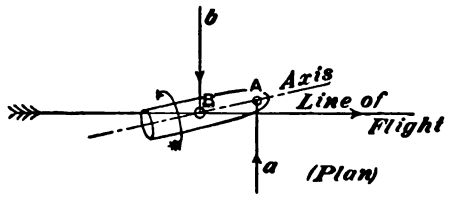

FIG. 4.
TO ILLUSTRATE OBLIQUE POSITION OF PROJECTILE IN RELATION TO LINE OF FLIGHT.

Of the two elements of the couple, a and b, it is seen that the force a, representing wind pressure, is the only one *acting from without*, and it is under the action of this force that the drift is produced; if we know the magnitude of the couple and the distance A—B, we can assign a definite value to the force a, and knowing the mass of the projectile, we can at once determine the acceleration of drift.

Now, I know of no direct way by which the position of the point "A" can be determined. This point may be described as the centre of lateral wind pressure for evanescent angle; it might be found by experiments conducted on a carefully suspended model, but it is doubtful whether complete reliance could be placed on experiments at any speed that would be practicable. Probably the only way of arriving at a value for the distance A—B is to deduce this from an actual measurement of the drift itself, thus inverting the problem in order to obtain the *constant* of any particular projectile.

It is not actually certain that the position of point A is absolutely constant in respect to velocity, but this can probably be relied on, provided that the range employed does not involve a critical velocity such as that of sound. In the absence of contrary data, it may be assumed as constant for our present purpose.

Now, let l be the distance between A and B.
v be the velocity of the bullet.
r be the radius of the trajectory.

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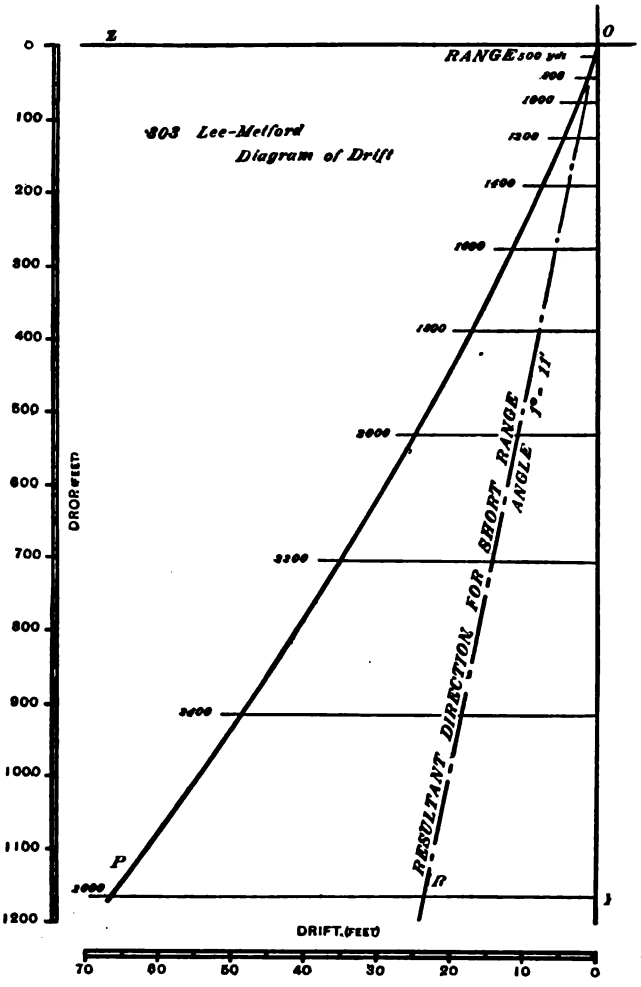

FIG. 5.—TO ILLUSTRATE "DRIFT" OF PROJECTILE.
(*The line O P is the projection of the path of the projectile on a vertical target.*)

Let ω be the angular velocity of bullet about axis of Z (due to curvature of trajectory).

M the moment of momentum of spin.

m the mass of the bullet.

f the lateral acceleration (*i.e.*, along the axis of Z) to which the drift is due.

Then

$$r = \frac{v^2}{g} \text{ and } \omega = \frac{v}{r} = v\,\frac{g}{v^2} = \frac{g}{v},$$

And couple $= M \cdot \omega = \frac{Mg}{v}$.

But couple also $= f\,m \cdot l$;

So we have $f\,m \cdot l = \frac{Mg}{v}$.

That is, $f = \frac{M \cdot g}{l \cdot m \cdot v}$, or $l = \frac{Mg}{f\,m\,v}$.

In the above expression it will be seen that the quantities l and m are constants depending upon the bullet alone, the quantity M depends upon the moment of inertia "I," and mass of the bullet, and pitch of rifling, multiplied by the initial velocity. I estimate the value of M for the ·303 Lee-Metford at 2000 ft./sec., as ·046 lb.-ft. ft./sec.

The value of g is taken as 32·2; a note will be found further on as to a small error introduced by neglecting the effective reduction in g caused by the "soaring" of the bullet.

If the range is sufficiently short, so that the velocity does not vary materially, then the value of f may be taken as constant, and the extent of drift bears a definite relation to the drop due to gravity; but in practice the velocity falls very rapidly, and the ratio of drift to drop increases with the range.

Thus in Fig. 5, if the point "O" be the axis of X and line O—P the projection of the path of the projectile on a vertical target, the curve will be of the form shown.

The exact computation of drift necessitates plotting the velocity curve as in Fig. 6, where the abscissæ represent time. Curve v,v,v shows the velocity as determined by experiment or known data. Curve f,f,f gives acceleration of drift calculated from our formula. Curve w, w, w is the first integration of the curve f,f,f, giving the velocity of drift at successive intervals of time; and finally, in Fig. 7, curve h,h,h gives the further integration showing the actual drift displacement.

I have taken the standard Lee-Metford rifle and service ammunition as the basis of calculation in the curves plotted in Figs. 5, 6 and 7, the former of which gives at a glance a comparison of drop to drift for ranges up to 2,600 yards, the ratio of scales being 10 : 1.

The data as to velocity, plotted as a curve in Fig. 6, were supplied to me by Mr. R. H. Hausman, and, I understand, calculated from Mr. Bashforth's tables. The "constant" on which the *scale* of drift curves (Figs. 5 and 6) is based was determined by careful experiment at 1000 yards range, the mean amount

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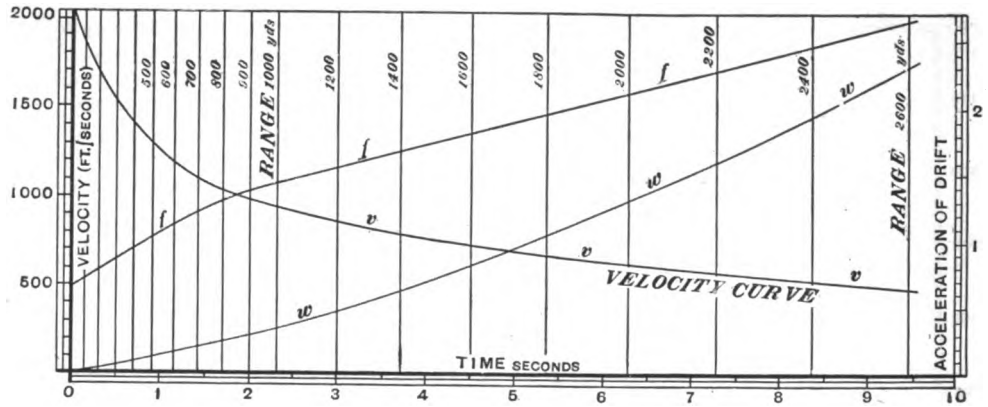

FIG. 6.—CURVES FOR VELOCITY (*v*), ACCELERATION (*f*), AND VELOCITY OF DRIFT (*w*).
(*Velocities are measured in ft./sec., and acceleration in ft./sec.*²)

being found to be 30″. I am aware that this figure differs from that frequently adopted, and that the exact determination of drift for some known range is at present wanting; but pending further experimental determination (which should, if possible, be made at about 1,400 or 1,600 yards range) I think the value may be accepted as being certainly within 10 per cent. of the truth.

The value of *l* for the Lee-Metford bullet on the above basis works out at 0·445 inch; that is to say, the effective centre of lateral pressure for evanescent angle is situated at about five-sixteenths from the nose of the bullet. It follows from our equation that the amount of drift varies inversely as this quantity *l*, and consequently any new determination may affect the value here given; conversely, if the value 0·445 in. appears in any way improbable, it will for the present cast doubt either on the method of investigation, or on the accuracy of the experimental determination of the actual drift referred to above.

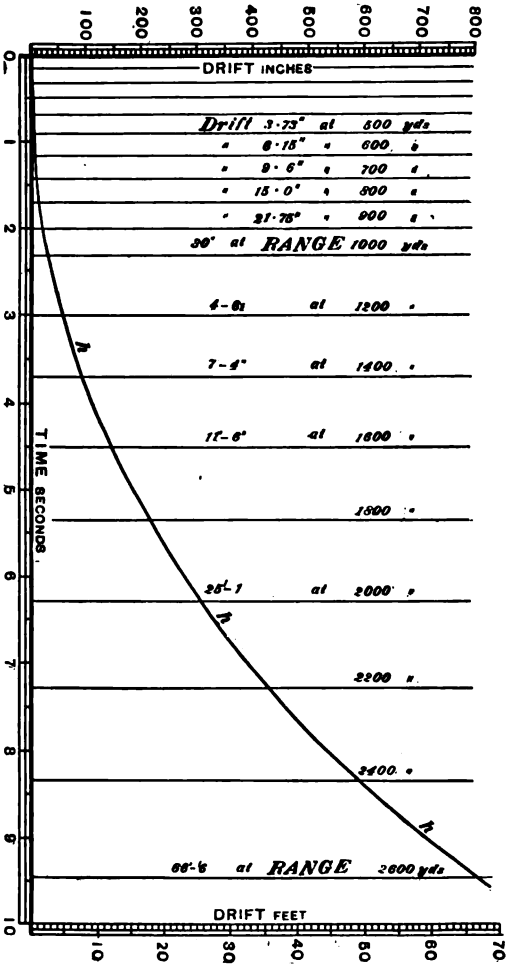

FIG. 7.—CURVES SHOWING ACTUAL DRIFT DISPLACEMENT.

It is of interest, therefore, to examine the question of the lateral wind pressure at small angle, with a view of testing the probability or otherwise of the figure we have obtained.

Fig. 8 illustrates a supposed case of the resolution of forces required by the conditions of the problem. It will be seen that the pressures on the bullet must be analysed into a force in the axis of flight passing through the centre of gravity, and a force at right angles. From the construction shown it would appear to be possible that the point "A" *might be* situated clear in front of the bullet, although this seems at first sight somewhat paradoxical; the actual interpretation is, of course, that the *real* couple *acting on* the bullet is in part due to the main resistance to flight not being aligned to the centre of gravity of the bullet as indicated by *e*,

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the further resolution of forces shown being necessary to obtain the position "A" as required by the assumption that the forces constituting the couple are transverse.

It would thus appear that although at first sight the amount 0·445 inch would seem excessive, as placing the centre of lateral pressure too far forward, closer examination puts quite a satisfactory interpretation on the matter.

It is impossible in a brief article to deal fully with secondary effects, but attention may be called to one point in respect of which the above figures may require a correction.

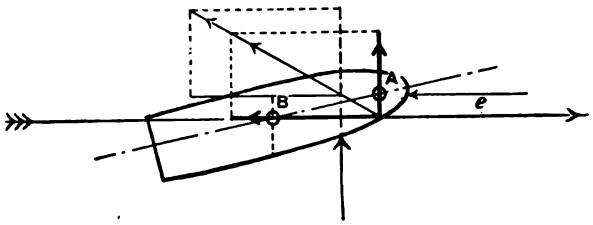

FIG. 8.—TO ILLUSTRATE RESOLUTION OF FORCES ACTING ON PROJECTILE.

It is an experimental fact that rifled projectiles in flight "soar" to a certain extent; that is to say, they do not drop as much as calculation would show, taking g as 32·2. One cause of soaring is without doubt the effect of "cut," owing to the axis being slightly oblique (sideways) to the line of flight. By "cut" is meant the action which takes place when a golf ball soars, or a tennis or cricket ball swerves in the air. In the above numerical work the value of g in the equation $f = \frac{Mg}{lmv}$ has been taken as 32·2 whereas, though commencing at this value, it diminishes considerably as the range increases. The effect of error introduced from this cause will be to make the values given by the curve at long range too high. An error in the same direction, but of very small magnitude, will be introduced owing to the falling-off of the value of "M" owing to the slowing down of the velocity of spin; it is believed that error from this cause is negligible.

The experimental determination of drift is not so easy a matter as might be expected; a range of 1000 or 1,200 yards is the least that is of real value, and almost perfectly still air is a *sine quâ non*. The Hon. T. F. Freemantle, in his "Book of the Rifle," confesses himself at a loss to judge between the different expert estimates, which vary from that of Mr. L. R. Tippins, who gives it as four feet at 1000 yards, to the "Musketry Regulations," in which it is given as 11 inches for the same range.

I venture to think that the drift diagram, Fig. 5, can be made of material assistance in bringing these widely different estimates into approximate harmony. Referring to the figure, it will be seen that the *true drift* is given by the departure of the curve OP from the axis of Y; but in order to exhibit this a match rifle, with spirit level and back sight set exactly at right angles, is necessary. If such a rifle, instead of having the level and sights set geometrically, were adjusted to shoot accurately at short range, say at 200 or 300 yards, the observed deflection at longer range will be an apparent drift given on the diagram by taking the resultant line O R as datum.

Now the apparent drift scaled from this diagram is about one foot at 1000 yards and two feet at 1200, but as the scale is very small I have calculated these quantities, and they come out as eleven inches at 1000 yards and 23⅓ inches at 1200 yards, and these figures are in remarkably close agreement with the "Musketry Regulations," in which the amounts are cited as 11 inches and 23 inches respectively.

Before concluding, it is worthy of remark that spherical bullets fired from a rifled gun drift in the reverse direction to that indicated. This is owing to the points "A" and "B" being coincident, and the axis of rotation consequently retaining its initial direction; then as the bullet drops, the effect of "cut" makes its appearance as a force acting laterally, and the direction of drift is negative. The negative drift sometimes reported with bullets of unusual shape or proportion is probably due to the same cause.

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ELECTRIC WAVES.

PART IV.—WAVE DETECTORS.

By J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London.

HAVING in the previous articles* considered the theory and production of electric waves, we may, in the next place, direct attention to the various devices which have been suggested or employed for detecting the presence of an electric wave, and utilising it telegraphically for the conveyance of information.

Our bodies are provided with a special organ, *viz*:—the eye, which enables us to detect the existence in any place of waves in the æther of which the wave length lies between 0·43μ and 0·75μ, where μ is the symbol for one micron, or 0·001 millimeter.

We can also detect longer waves, which have no effect upon the eye, by the sensation of warmth they produce when falling upon the skin surface, provided they are sufficiently intense. We may, however, say that we have no natural organ which enables us to determine the presence in any place of æther waves of wave length greater than about 70μ to 100μ.

It is well known that beyond the limits of the ultra red spectrum there is a range of æther waves which have as yet not been manufactured or discovered. The wave length of the shortest waves which have yet been created by the electrical method already described, *viz.*, by the discharge of a condenser, is about three or four millimeters, or 3,000μ to 4,000μ. Waves of a similar type, of hundreds or even thousands of feet in wave length, have been employed in wireless telegraphy. It is possible that the sun itself emits Hertzian waves, and there is practically no upper limit to the wave length. When therefore we speak of electric wave detectors, we mean devices for determining the presence in the æther of wave motions, either isolated pulses or trains of waves, the wave length of which lies between three or four millimeters and any far greater length.

As a large number of such devices have now been invented, a word is required to include them all. Just as we use the word *electroscope* to denote all the various varieties of instrument for detecting electrification, so the author has suggested the use of the word *kumascope* (from κυμα = a wave) to denote all forms and kinds of electric wave-detecting device, whatever their nature. A qualifying adjective may be employed with it to describe special varieties of kumascope. To understand the essential nature of a kumascope, we must recall to mind the nature of an electric wave. We have already explained (see TECHNICS for September, 1904) that an electric wave consists in an alternation of electric and magnetic force at any place, these forces being at right angles to each other and to the direction in which the wave is travelling. To detect an electric wave in space we require some appliance which is very sensitive to rapid alternations of electric or magnetic force, or, in other words, to very feeble electromotive forces or electric currents.

Let us suppose that two rods of metal are placed in one line, with their ends in close contiguity (say, a small fraction of a millimeter apart). Let an electric wave be incident upon them, so directed that its electric force is parallel to the rods. Then, as the crest of the wave sweeps over these rods, the small air gap between them will be subjected to an alternating electric force. If this force at any moment exceeds in magnitude 150 electrostatic units or so, the air film will be transformed instantly into a conductor, and will be traversed by an electric current and made hot and luminous. This constitutes what is called an electric spark.

Hence the first and simplest form of kumascope is the *spark kumascope*. There is no question that many effects due to electric waves were observed long prior to the date when a clear knowledge of electric wave phenomena was first obtained.

Joseph Henry, in 1842, made some remarkable experiments on the action of electric sparks in magnetising steel needles at a distance, which induced him to give his adherence to the idea of an electrical medium. Many years ago, Edison, Houston, S. P. Thompson, and others had noticed curious effects in which small sparks were produced between metal surfaces by an action to which

* See TECHNICS for August September and October

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the name of *etheric force* was given; but it was the penetrating genius of Hertz which finally explored this phenemenon in a sufficient manner, and unravelled the tangled skein of facts connected with it.

To present the facts in the most simple manner, let us imagine two pairs of metal rods, each rod, say, six feet in length; and let each pair of these rods consist of two rods placed in line with one another, one such pair being placed with its rods parallel to those of the other pair. Suppose the contiguous inner ends to be provided with spark balls placed very near to each other. We shall assume that the pairs of rods are placed 10 or 15 feet or more apart. We shall call one pair the *transmitter rods*, and the other pair the *receiver rods*. Let the spark gap in the first pair be made five or six millimeters in length, and that in the receiver pair one-tenth of a millimeter. An induction coil has its two secondary terminals connected to the two transmitter rods respectively, and when this coil is set in action, a small bright crackling spark will pass between the transmitter spark balls. These balls must be highly polished. If, then, the receiver rods are suitably adjusted, and we make the spark gap sufficiently small, we shall, in a dark room, find a small spark passing between the receiver balls. The explanation of this effect is as follows: As the induction coil creates a difference of potential between its secondary terminals, so the rods attached to them acquire a difference of potential, one being charged positively and the other negatively. When a certain intensity of the electric force in the spark gap is reached, the air insulation breaks down, and the rods lose their charge. These rods, however, have electrical capacity with respect to each other, and the discharge is, therefore, similar to the discharge of a Leyden jar when the dielectric is suddenly pierced. The discharge is, therefore, as already explained (see TECHNICS, October, 1904), oscillatory in character. If we now picture to ourselves the lines of electric strain or electric force round the rods before discharge, they will be somewhat as represented in Fig. 1. If the oscillatory discharge has a sufficiently small period, then this signifies that the rods are traversed by a very rapid alternating current, alternating with the periodic potential difference. At one moment the rods are at different potentials, and the space round them is filled with lines of electric strain; at the next moment there is an electric current flowing across the spark gap, and not only abolishing the difference of potential, but creating it again in an opposite direction. At the time when the current is flowing, the space round the rods is occupied by magnetic lines, disposed in concentric circular curves with their centres on the rods.

If the oscillations are sufficiently slow, this process would merely result in the periodic establishment of lines of electric strain and magnetic force which would never become detached from the rods. If, however, the oscillations are rapid, then each oscillation is accompanied by the detachment from the rods of closed loops of electric strain, which move away through space and carry with them energy.

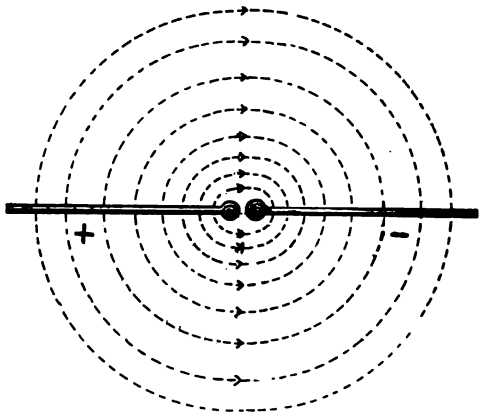

FIG. 1.—ROUGH REPRESENTATION OF LINES OF ELECTRIC STRAIN NEAR A LINEAR OSCILLATOR.

The manner in which this happens can best be understood by looking at the diagrams in Fig. 2, which represent the successive stages in the reversal of direction of the line of electric strain springing from one rod to the other, and the mode in which the loop of electric force is thrown off by the decussation or crossing of the lines. This decussation is due to the fact that the æther possesses inertia, and hence the line of strain cannot be instantaneously created or abolished in any direction. It is this detachment of lines of electric strain which constitutes electric radiation. Strictly speaking, it would be more correct to say that the closed loop of electric strain dies away at one place, and is recreated subsequently at an adjacent one. The reader must bear in mind the two fundamental characteristics of a line of electric strain, *viz.*: that it tends to contract itself, or behaves like an elastic thread, and that its lateral or sideways movement through space gives rise to lines of magnetic force.

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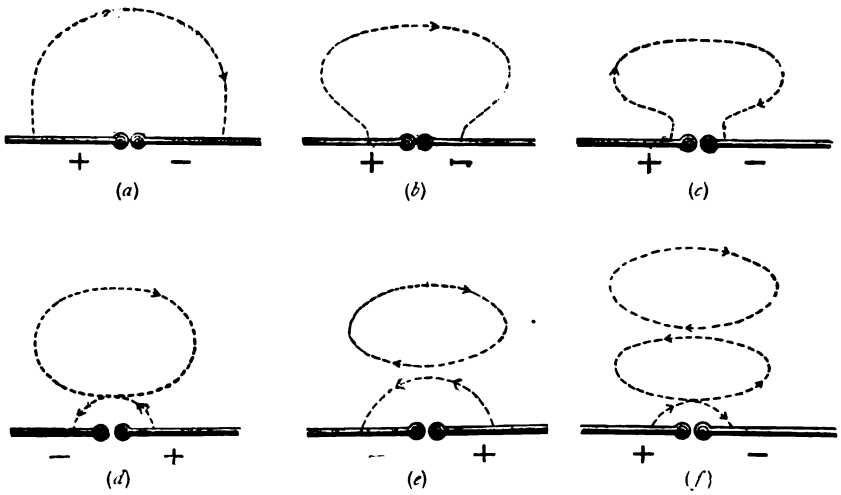

FIG. 2.—SUCCESSIVE STAGES IN THE CREATION OF CLOSED LOOPS OF ELECTRIC STRAIN BY THE ACTION OF A LINEAR OSCILLATOR.

the direction of which is at right angles to the line of electric strain and to the direction of motion. Accordingly it will be clear that a closed line of electric strain cannot persist permanently in the æther. It at once begins to shrink up to nothing. In so doing, however, it creates a stream of magnetic flux which flows, as it were, through the interior of the loop of electric strain and back again over the outside. This magnetic flux, as it increases or decreases in amount, re-creates electric strain along closed lines in the space enclosing the varying magnetic flux. Hence we have an effect produced equivalent to a progression through space of co-ordinated lines of magnetic flux and electric strain. We have, in the next place, to consider what happens as these travelling lines of magnetic flux cut through the receiver rods.

In the case of a dynamo, the electromotive force in the armature is created by the copper wires moving across the lines of a magnetic field. If, however, we consider the copper wire to be at rest, the same electromotive force would be generated if the magnetic field lines were to move across or cut through the copper wire. So it is in the case of the receiver rods. If these rods are parallel to the transmitter rods, then they are at right angles to the direction of the moving magnetic force lines sent out from the transmitter. Hence, as these latter cut across the receiver rods they induce in them an electromotive force. Since the receiver rods have capacity with respect to each other, the result is to generate in them an alternating current of very high frequency, which flows backwards and forwards in the rods, and has the same period as that of the current in the transmitter rods. The result, therefore, is the same as in the case of ordinary electric current induction between parallel circuits. The student must, however, carefully notice the difference between the two phenomena. Suppose the transmitter and receiver rods to be parallel and quite near. Then if we set up in the transmitter rods an alternating current of low frequency, it would create an alternating magnetic field, and also by ordinary induction a secondary induced current in the receiver rods. In this case the secondary current is due to the pulsating magnetic field of the primary cutting through the secondary circuit.

There is, however, no detachment of the lines of magnetic force from the primary circuit or the transmitter rods. If, however, the current in the transmitter rods is of such a high frequency as to be properly called a Hertzian oscillation, then the magnetic flux lines are detached from the transmitter rods and travel away through space, the energy of the original electric oscillations in the rod being totally removed from the rods, and existing in the medium as a state of electric strain and magnetic flux, propagated from point to point through it.

Hence, when these travelling lines of magnetic flux intercept a conductor, they create in it electromotive force and an induced current.

One method, therefore, of detecting electric

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radiation consists in placing in the space a metallic rod or wire, having in its circuit at some point a device or instrument responding in some way to the presence of a high-frequency alternating electric current or electromotive force which may exist in the rod circuit. This rod must be so placed that its length is at right angles to the direction of the magnetic force of the wave. In the rod circuit must be placed one of the devices which the author has collectively called kumascopes, or wave-detecting devices. These kumascopes generally may be divided into four great classes :—

1. Contact kumascopes.
2. Magnetic kumascopes.
3. Thermal kumascopes.
4. Electrolytic kumascopes.

The first class comprises all those kumascopes which operate in virtue of the fact that when a difference of potential is made between two pieces of metal or other substance, in light contact with one another, either the two pieces cohere together more strongly, or else they cohere together less strongly.

These facts were chiefly discovered by Professor Branly. In 1890 and 1891 Branly found that, when two pieces of metal, such as lightly oxidised steel needles, were placed in contact one with the other under very slight pressure, the creation of an oscillatory spark in the neighbourhood caused these two pieces of metal to cohere together more strongly, and the "loose contact" became a "good contact," through which an electric current could be sent from a voltaic cell, giving an indication of a galvanometer or an electric bell. Branly also discovered at the same time that certain other substances, such as peroxide of lead, behaved in a different manner, and that the contact between two pieces of this substance is made less perfect, and not more perfect, by the action of an oscillatory spark in the neighbourhood. It is not clear, however, that Branly recognised this action as due to electric waves; and it is difficult to say what period of time elapsed before it was clearly and definitely understood that this action was due to the operation of an electric wave. In the year 1894, however, the facts were clearly set out by Sir Oliver Lodge in a lecture delivered at the Royal Institution; from and after that date it was clearly recognised that an instrument then called the *coherer* could be employed to detect electric waves.

One form of Branly's apparatus consisted of a small vessel or box, containing metallic filings, and it was found that these loosely aggregated particles of metal had a very high electrical resistance in their normal condition, but became greatly reduced in resistance under the action of an electric wave. Previous experiments, however, by Onesti had shown that the passage of an electric current through metallic filings was sufficient to weld them together into a fairly good conducting mass. Much discussion has taken place as to the precise cause and nature of this operation. Very great differences exist between the different metals in regard to this property; thus iron, nickel, and cobalt, the three magnetic metals, exhibit in a very marked manner this property of coherence; but it is much less marked in the non-oxidizable metals. Hence Marconi found that by suitably mixing together filings of nickel and silver—about 5 per cent. silver and 95 nickel—and including an extremely small quantity of this powder in a glass tube between silver plugs, he was able to make an instrument of extreme sensitiveness for the detection of electric waves. (See Fig. 3.) In some cases the coherence, which is established by the passage of the alternating current through the mass of metallic filings or the loose metallic contact, remains after the stimulation ceases. To restore the filings to their original condition, a small tap has to be administered; or, if the filings are composed of a magnetic metal, they may be disturbed magnetically. In other cases, such as the contact between a globule of mercury and a carbon or steel rod, the coherence established by the passage of the electric ceases spontaneously when the oscillation ceases.

Hence we may divide these contact kumascopes into three well-marked classes :—

First. Those in which improved coherence and lowered resistance accompany the passage of an electric oscillation through the contacts, but which require to be tapped mechanically, or disturbed mechanically, to bring them back to their original condition.

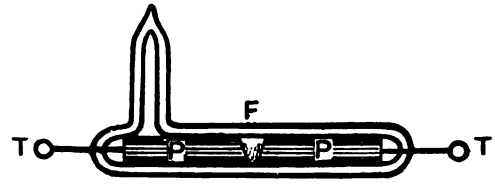

FIG. 3.—MARCONI SENSITIVE TUBE OR KUMASCOPE.

P, P, *silver plugs.* T, T, *platinum terminals.*
F, *nickel-silver powder.*

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An illustration of such behaviour is afforded by the ordinary Marconi sensitive tube, or a simple tube of iron filings, or the light contact between a steel needle and an aluminium plate. Such appliances are properly called *non-self-restoring kumascopes.*

Secondly. Another class of contact kumascope comprises those contacts in which the increased coherence or diminished resistance vanish spontaneously when the electric oscillation ceases; these are properly called *self-restoring kumascopes.* As an example of this class may be mentioned the form of coherer commonly called the Solari, or the Italian Navy coherer, but by some writers attributed to Tommasina, and also to Castelli. This consists of a globule of mercury in a glass tube included between two steel or carbon plugs, a very light contact being adjusted.

Another instance of a non-self-restoring kumascope is the Lodge and Muirhead device, in which a steel wheel touches a mercury surface covered with paraffin oil. The coherence of the steel and mercury is continually destroyed by rotating the wheel.

The third class of contact kumascope includes those in which the resistance increases instead of diminishes, or in which the coherence is made worse instead of better. An example of this kind of kumascope is the lead and peroxide of lead contact devised by Mr. S. G. Brown. In this arrangement one piece of lead, which is peroxidised on the surface, has a lead point pressed very lightly against it. When an electric oscillation passes through this contact it causes the resistance to increase, but this increased resistance spontaneously vanishes when the oscillation ceases.

Any one of the above appliances becomes the means for detecting an electric wave, when it is inserted in the circuit of a long wire so placed as to have its direction parallel to an electric force of an incident wave.

The kumascope may be acted upon directly by the alternating current, or oscillation set up in its rod; or it may be acted upon inductively by means of a small air-core transformer, one circuit of which is inserted in the receiving wire, and the other has its terminals connected to the terminals of the kumascope.

The next great class of kumascope comprises the magnetic detectors. As far back as 1841 Joseph Henry discovered that steel needles could be magnetised or demagnetised by the action of electric oscillations flowing through wires surrounding them. Rutherford, in 1896, carried out a valuable series of experiments on this subject at Cambridge, and showed that a very feeble oscillation set up by a Hertzian wave in a receiving wire is sufficient to demagnetise feebly-magnetised bundles of steel wire.

Marconi, in 1902, described an extremely sensitised form of magnetic kumascope. It consists of an endless band of fine iron wires passing round two pulleys (see Fig. 4), and caused to move forward in one direction by means of clockwork. At one part in its path the iron wire band passes through two coils of wire overlaid. One of these is a short, thick wire, which is in the circuit of the aerial or the receiving rods, and the other a fine wire coil connected with the telephone. Two permanent magnets are placed as shown in Fig. 4, and magnetise a portion of the iron wire opposite to them. Owing to the property of the iron called *hysteresis*, in virtue of which it retains magnetism after the magnetising force has been withdrawn,

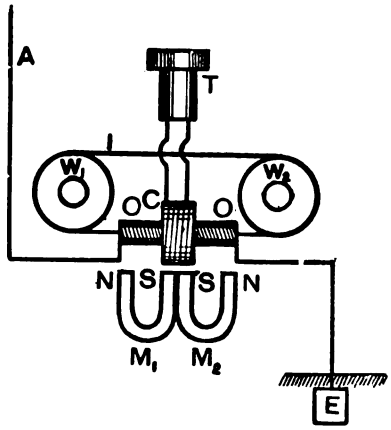

FIG. 4.—DIAGRAM OF MARCONI MAGNETIC KUMASCOPE.

W_1, W_2, *wooden wheels driven by clockwork*; I, *iron band*; M_1, M_2, *permanent magnets*; T, *telephone*; O, O, *oscillator coil*; C, *secondary coil*; A, *aerial*; E, *earth plate.*

the magnetised portion of the iron band is not exactly opposite to the poles of the magnet, but is displaced in a forward direction: that is, in the direction in which the band is travelling. If an electric oscillation passes through the thick wire coil it suddenly destroys the hysteresis, and the magnetised portion slips back, as it were, suddenly into a position exactly opposite to the poles of the magnets. This operation causes an induced current in the fine wire coil, which

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is caused to affect the telephone, and makes itself evident as a slight tick or noise.

More recently Ewing and Walter have found that, under some conditions, the hysteresis of steel wire can be increased and not diminished by electric oscillation.

The third class of kumascope comprises the thermal instruments. Since an electric oscillation is only an alternating current of very high frequency, it enjoys the property common to all electric currents of heating a conductor through which it passes. Hence, if a very fine wire is inserted in the path of the electrical oscillations, it becomes heated and its resistance becomes increased. This increase in resistance may be detected in several ways. The fine wire may form one arm of a Wheatstone's bridge, and the change in resistance may be rendered evident, either by a very sensitive galvanometer or by the employment of a telephone. Inasmuch as liquids have a larger co-efficient of temperature change than solids, a very fine column of liquid contained in a glass tube has been employed instead of a fine wire. Thermal instruments of this kind, designed to detect electric oscillations, have been invented by Fessenden, Duddell, Stone and others. Fessenden employs either an exceedingly fine platinum wire mounted in a vacuous glass bulb like a filament of an incandescent lamp, or else a very fine column of liquid contained in a glass tube.

The fourth class of kumascope embraces the electrolytic instrument, and also those which depend upon the establishment of a chain of metallic filings which is broken up by the electrical oscillations. In one form of detector invented by De Forest, an electrolytic liquid containing metallic solids is electrolysed by means of a feeble electric current, and establishes between metallic electrodes a chain of metallic particles; an electric oscillation passing through this cell breaks up these particles and so increases its resistance.

The space at our disposal will not permit us to discuss more in detail the different kinds of kumascope.

We must, however, make reference to the manner in which these are employed. From what has been already said, it will be seen that the kumascope itself has to be associated with a long receiving wire, or wires, of some kind, the function of which is to become the seat of an electromotive force induced as described by the impact of the wave.

The kumascope must, therefore, be inserted in the run of this wire. There are several ways in which this may be done. First, the kumascope, whatever its nature, may be placed in the centre of the receiving wire; in other words, the terminals of the kumascope are provided with two long metallic extensions. These receiving wires must be so placed that they are parallel to the electric force of the wave or the right angles of its magnetic force.

Secondly, the kumascope may be inserted between one long vertical aerial wire and the earth. This is particularly the method of Marconi, and is an absolutely essential condition for long-distance signalling. In either case the kumascope may be acted upon directly by the oscillations existing in the aerial wire, or it may be acted upon by a secondary oscillation induced in the secondary circuit of an air-core transformer, the primary circuit of which is inserted in the circuit of the aerial wire.

In the next place, we may note the manner in which the kumascope is caused to give an indication of some kind, so as to record a signal. Generally speaking, the change, whatever its nature, which is produced in the kumascope by the electrical oscillation generating the receiving wire, is not directly apparent to the senses, but something has to be done to the kumascope in order to detect the change thereby produced. Thus, for instance, if a metallic filings kumascope is connected between an aerial wire and the earth, as in the case of the original Marconi receiver, the effect produced in the kumascope is a reduction in resistance. This is detected by connecting, also in series with the kumascope, a single cell and a galvanometer or a telegraphic relay or some instrument which will render evident the sudden fall in resistance in the mass of the metallic filings. In the case of the contact kumascopes, the change in resistance in the kumascope, whether an increase or a decrease, is generally caused to close or open the circuit of a sensitive telegraphic relay, and this last instrument in turn is caused to operate a Morse printer. As an alternative, we may employ a syphon recorder and connect it directly to the kumascope, inserting in series a source of small electromotive force.

Another method by which the change in the kumascope is detected is by the employment of a telephone. It has already been pointed out that in the case of Marconi's magnetic detector the change in the magnetic state of the iron wire is caused to create an induced current which acts upon a telephone. In the same way, when employing a thermal

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or electrolytic kumascope, the sudden change in resistance that takes place may be caused to create a sound in a telephone, by permitting a sudden increase in the current flowing from a small electromotive force through the telephone. These two methods of detection are respectively called the telegraphic and the telephonic methods. When using a kumascope as a means for conducting wireless telegraphy, the alphabet has to be created on the Morse system, either by printing on the Morse tape long and short marks, or making in the telephone long and short sounds. When using a non-self-restoring kumascope, such as a metallic filings tube, associated with a Morse printer and an ordinary electro-magnetic relay, it is impossible, on account of the mechanical inertia of the various parts of this chain of apparatus, to send words at a greater rate than 15 or 18 a minute on the Morse code.

On the other hand, when using a telephonic receiver, with a magnetic or electrolytic detector, it is possible to receive 30 to 35 words per minute—in fact, as fast as good hand sending can be effected.

(*To be continued.*)

COLOUR PHOTOGRAPHY: THE THREE-COLOUR PROCESS.

By COLIN N. BENNETT.

AMONG the many methods of photographing objects in their natural colours, one only has so far attained a position of commercial importance. This is the three-colour process, in which three separate negatives of the original are photographed by means of light transmitted through red, green and blue screens respectively. From these three negatives it is possible to reproduce an image of the original in its correct colours, either by the process known as triple projection, or by another process to be discussed later on.

The three-colour process first came before the notice of the scientific world in May, 1861, when Clerk Maxwell demonstrated the method of triple projection before the Royal Institution. It depends on the principle that all colours in nature may be simulated to the eye by a mixture of *red*, *green* and *blue* light rays. When these are mixed in certain proportions, which vary slightly for different individuals, they give the effect of white. When red and green lights only are mixed, the resulting colour sensation is yellow; while a mixture of green and blue lights produces a sensation of blue-green, and a mixture of red and blue rays produces a sensation of pink. Further, it is possible to simulate any other colour at will by the judicious blending of the primaries: thus, orange is a mixture of red and green lights, the red being in preponderance; and so on. *Pink*, *blue green* and *yellow* are known as the three complementary colours. It will be noticed that each of these is equivalent to white light deprived of one primary colour. Thus we may say that pink is white light *minus* green, blue-green is white light *minus* red, and yellow is white light *minus* blue.

Let it be granted that we can produce three negatives of a given object which are records of these three colours; then there is no reason, provided a suitable printing method be obtained, why we should not be able to produce a photograph in the natural colours of the object.

Since colour-sensitive plates were unknown in the sixties, Clerk Maxwell was unable to very successfully put his method into execution; it is essentially as follows:—

Having obtained three negatives by the use of suitable coloured screens or "light filters," three positives are made from them, in black-and-white, by the usual method for obtaining a photographic transparency. Each of these is next bound up with the light filter through which the corresponding negative was taken, and the three are simultaneously projected on to a screen by means of three magic lanterns, and adjusted so that the images are superposed in correct register. The result is a picture of the original in its natural colours. The reasoning underlying this process is simple. Suppose the object photographed to be a yellow flower with green leaves, in a red flower-pot. The negative taken through the red screen will register a deposit of silver for both the flower and the pot, since yellow as well as red objects reflect red rays. The green, however, will be registered by no deposit, *i.e.*, the green parts of the image will be represented by clear glass, since green does not reflect red rays. The negative

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taken through the green screen will register both the flower and leaves as a deposit: it will be remembered that yellow is a mixture of red and green lights, so that a yellow object reflects green rays. The pot will in this case be registered as clear glass. The negative taken through the blue screen will show no deposit whatever for either flower, leaves, or pot, since neither of these reflects blue rays. Of course, in positives made from these three negatives the positions of deposit and clear glass will be exactly reversed.

On binding the positives up with the respective screens through which they were taken, and projecting them as before described, there will be an image of flower and pot projected in red upon the screen, also an image of leaves and flower projected in green. There will be no image projected in blue. Thus, we see at once that the pot is shown red and the leaves green, as in the original. The flower is represented by superposed images in red and green, which colours, as we have seen, make yellow. This completes the illustration.

This process is, in itself, of no commercial utility, but it illustrates the principle upon which Ducos du Hauron invented his system of triple film heliochromy. In this, three positives are made from the three record negatives in colourless gelatine relief. Transparent celluloid is coated with a thin layer of soluble gelatine containing silver bromide. A one per cent. solution of potassium bichromate is then applied to the gelatine, and after drying, the film is ready for exposure. Each negative is exposed in contact with one of these films: the part of the gelatine exposed to light is rendered insoluble, while the remaining portion can be removed by floating the film, face downwards, on water at 100° F. The relief is then dyed to the tint complementary to the colour of the light-filter by means of which the corresponding negative was taken, *viz.*: blue-green for the positive corresponding to the red record negative, pink for that corresponding to the green negative, and yellow for that corresponding to the blue negative. These three tinted positives, when bound together in register, give a transparency which very accurately represents the colours of the original.

It may be advisable to explain the reasoning by which this result is arrived at. Reverting to the illustration of the flower and pot, the positive obtained from the red record negative will be dyed blue-green, *i.e.*, the print will represent the leaves in blue-green, the rest of the plate being transparent and colourless. The positive obtained from the green record negative will be dyed pink. This will give a representation of the pot only in this colour. The positive from the blue-violet record negative will, on dyeing, be an image of the whole, flower, leaves and pot, in yellow. Fig. 1 will make this clear.

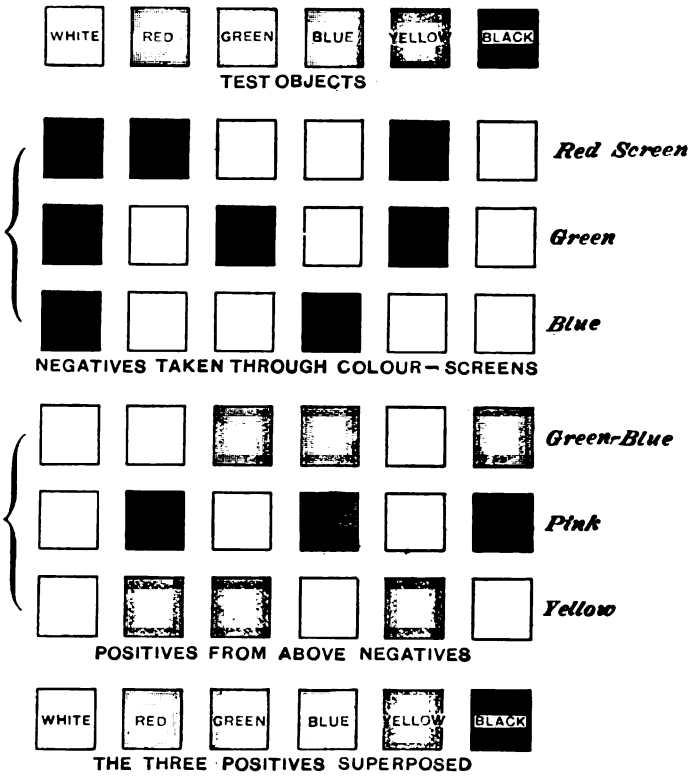

FIG. 1.—TO ILLUSTRATE THE METHOD OF T E FILM HELIOCHROMY.

Let these coloured prints be superposed in register. On viewing them against the light, the white light filtering through the films will be deprived, on passing through the image of the leaves, first of red (since the blue-green film is opaque to red), and then of blue (since the yellow film allows only red and green

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light to pass, and is, therefore, opaque to blue). Thus, it is clear that the only colour which will penetrate this part of the transparency is green, and the leaves appear in their proper colour. Similar reasoning can be applied to the rest of the transparency.

Having now explained the principle which underlies the three-colour process, it will be advisable to briefly review the methods at present in vogue, by which the above-mentioned colour positives are made.

Here the first thing that claims our attention is the subject of light-filters. These are of two kinds, liquid and solid. The former are best for scientific experimentation, but the latter are far more convenient in actual practice.

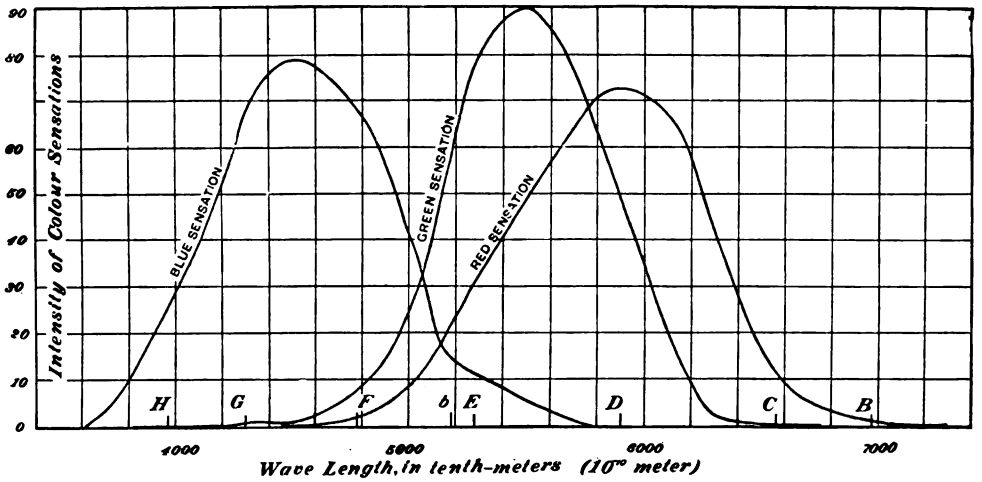

FIG. 2.—SIR W. DE W. ABNEY'S CURVES, SHOWING THE INTENSITIES OF THE VARIOUS COLOUR SENSATIONS EXCITED BY DIFFERENT WAVE-LENGTHS OF LIGHT.

The usual method of preparing a solid light-filter is to coat thin optically-worked glass with an even film of gelatine. This is best done by means of a coating machine. Pieces cut to the desired size are then dyed in baths of aniline dye, which have been carefully adjusted with regard to correct colour absorption. They are then dried and finally cemented together by means of Canada balsam.

The next question is the adjustment of the light-filters to let through only the most suitable rays. Clerk Maxwell first indicated the rays by means of his colour-mixture curves. Sir W. de W. Abney re-determined these curves, and found a more correct position for the three colour sensations. These correspond to wave-lengths of 6,705, 5,140, and 4,600 tenth-meters for the red, green, and blue sensation respectively. The curves as re-determined by him in 1899 are shown in Fig. 2. We must not use too narrow bands of the spectrum; but exactly how wide and how sharply cut off these should be, has of late formed a subject of controversy. There is a very good reason why the spectrum bands utilised should not be too narrow. Owing to the imperfect orthochromatisation of even the best colour-sensitive plates, it is often found that the sensitiveness varies very greatly between adjacent portions of the spectrum.

This leads up to our second subject, namely, colour-sensitising. There are many dyes used for this purpose, notably eosin and erythrosin for the green and yellow rays, and cyanin for the red. These are used in very dilute ammoniacal solution. Recently, however, ethyl red, and still later orthochrome T, and pinachrom, have been much talked of as red sensitising agents. All these modifications of cyanin, when pure, also act as green sensitisers. A plate which has been rendered sensitive to practically the whole of the spectrum is generally known as "panchromatic." There are many excellent brands of panchromatic plate on the market which are quite suitable for the process. Since treatment with a colour-sensitising solution alters both the scale of gradation and length of exposure of a plate, it is necessary that precisely similar plates shall be used in making all three-colour record negatives; not a specially green-sensitive plate for the green record, a specially red-sensitive plate for the red record and so on, as this would result in inaccuracy of the colour scale in the resulting photograph.

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The method of obtaining the positives in relief has already been described. The colours used for dyeing these reliefs are the complementaries of the red, green, and blue primary sensations of Clerk Maxwell.

There are three positions in which the light filter may be fixed. These are directly before or directly behind the lens, or directly in front of the sensitive plate. The position is chosen according to convenience, provided optically worked glass is used to support the coloured film; the nearer the light filter is to the plate, the less effect will any slight inequalities in the glass have upon the resulting negative.

Since it is necessary for the production of a three-colour photograph to make three negatives identical in form, many devices have naturally been invented for securing these in the shortest possible space of time and with a minimum of vibration. A very satisfactory arrangement was the slide on carrier due to Mr. F. E. Ives. Mr. Sanger Shepherd has invented a single-lens camera by means of which all three negatives may be taken with one exposure.

Now, to proceed to the taking of a three-colour photograph. The first thing to be done is to find the exposures required through the three screens, and also the exposure required for an ordinary photograph taken under similar conditions. These particulars are obtained as follows:—

Set up a suitable test object. Let this be a white plaster cast, or piece of crumpled paper.

By means of an exposure meter find the time required to produce an ordinary negative. Take such a negative on one of the colour-sensitive plates, develop and fix it; also take a negative of the same object under similar conditions, but using the red screen as a light filter. Develop this also and fix it, then compare it with the negative previously taken. From comparison with the first negative, alter the exposure till equally good results are obtained in both cases. The ratio of the time taken when using the red filter to that taken in obtaining an identical negative without it, gives the number by which the normal exposure must be multiplied in order to find the exposure for the red record negative.

By a similar process of trial and error the times of exposure for the green and blue record negative can be found. They are generally somewhere about—red 300, green 200, blue 100 times normal exposure. These results, of course, are only approximate, since the actinic quality of daylight varies from hour to hour and from day to day: this forms an inherent difficulty in the three-colour process; but for practical purposes, with the data obtained in the manner just described, it becomes comparatively easy to make the three negatives required for printing.

For development, a slow non-fogging developer should be used, such as weak metol or pyrocatechin. The negatives should be developed to considerably less density than is usual in monochromatic photography. Printing is effected by exposing the gelatine-coated celluloid through the negative, the celluloid side of the printing tissue being placed next to the film in the printing frame. Exposure occupies about two minutes in diffused daylight. Development of the tissue is effected by floating it face downwards on water kept at a temperature of 100° F. until the superfluous gelatine has dissolved away, leaving the image as a relief upon the support.

The silver bromide is next removed in an ordinary fixing bath, and after careful washing it is ready to be dyed as before mentioned.

The dyed tissue should be given a quick rinse in water to remove any superfluous colour from the high lights. After this all that remains to be done is to bind these three positives together in register, when a natural colour transparency will be obtained.

Should either colour appear too strong, it must be slightly washed out by rinsing in water; if too weak, the film should be further dyed in the colour bath. The process at this point becomes a matter of judgment and careful manipulation. When a satisfactory result has been arrived at, the positives are bound between sheets of cover glass, or, better, sealed between them by means of Canada balsam.

The above is the three-colour process as applied to the making of transparencies or lantern slides. Quite recently a method has been worked out by Mr. Sanger Shepherd, by means of which it is possible to obtain a colour photograph on paper. He employs three positives produced on gelatine of a particularly hard composition, which are dyed in special dye baths. These are then "squeegeed" in turn, in optical contact with a gelatine-coated paper containing a suitable mordant. A transfer of dye is thus effected, and the result is a surprisingly accurate reproduction in colour upon paper. This process has been used with great success for the reproduction of miniatures, and marks the last step of progress in this direction. There is still, however, a wide field for further serious work on this subject.

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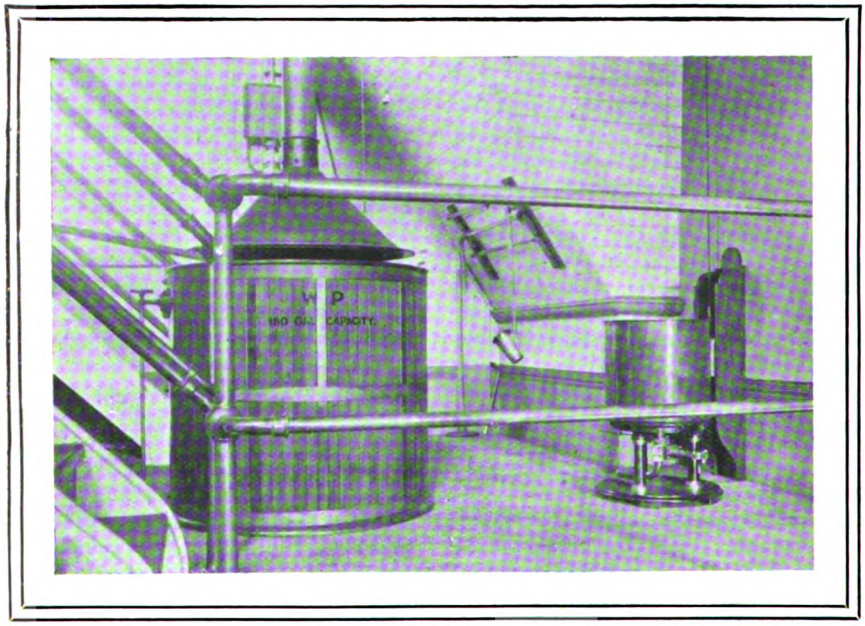
THE PREPARATION OF ENGLISH BEERS.

PART II.

By JAMES GRANT, F.I.C., F.C.S.



WORT COPPER AND SUGAR VESSEL IN THE MANCHESTER SCHOOL OF BREWING.

BREWING PROCESSES.

IN England, brewing is carried out by the "Infusion system." Certain modifications may be added, such as the use of a converter, hot-grist mashing, the semi-decoction system, and the like.

All water used for actual brewing must first be boiled and cooled to the proper temperature.

The malt should be crushed (not ground) to suit the conditions obtaining in the brewery.

The usual processes in English breweries are :—*Mashing*, to produce the wort or sugar solution ; *sparging*, to wash out the extract from the grains ; *boiling with hops*, to sterilise and give the proper flavour and aroma to the wort ; *cooling* to the proper pitching temperature ; *fermenting*, to obtain the alcoholic beverage ; and *finishing* of the beers in the cellars.

Mashing.—The first and most important of all the brewing processes is that of mashing.

Water of the proper type and temperature is mixed with the suitable grist, either by an outside mashing apparatus such as a modified Steel, or in the mash-tun by the aid of rakes or paddles.

In this way a mass of porridge-like consistency is obtained, which mixture is allowed to remain in the mash-tun for a "stand on" of two hours, during which time the enzymes of the malt grist convert the malt starch into sugars, intermediate bodies, and dextrins ; while the albumenoids or proteids are broken down and changed into peptones, amides and other yeast foods.

Both the foregoing reactions are examples of hydrolysis, involving the addition of molecules of water and degradation to simpler bodies.

After standing for two hours to ensure complete conversion of the malt-starch, the wort or sugar solution is run off into the coppers, and sparging is proceeded with, in order to wash out any remaining extract from the grains as soon as formed by the enzyme action.

The wort is now boiled for a short time, then hops are added to it, and the

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boiling continued. The objects to be attained are—the sterilising of the wort, the concentration of it, the deposition of certain matters which tend to render the finished beer unsound, the aeration, and the giving of the proper flavour and aroma by means of the hops. This part of the process generally takes about two hours.

The boiled, hopped wort is next run into a hop-beck—an iron vessel of suitable dimensions fitted with a false bottom. On this false bottom the hops settle to form a filter-bed. On its way to the cooler for further aeration the wort passes through the bed of hop cones, by which it is filtered quite bright.

While on the cooler, the wort absorbs much oxygen, and at the same time deposits a brownish compound known as "cooler-sludge." It next descends over the refrigerators, which cool it down to the correct pitching temperature of about 60° F. In this passage a further deposition of cooler-sludge takes place. From the refrigerators, the wort is collected in the fermentation vats, where its volume is gauged, and the strength and temperature ascertained. It is then "pitched" or mixed with the proper quantity of yeast and allowed to undergo fermentation.

A Copper for Boiling the Wort with Hops.

Three systems of fermentation are in vogue in this country: The skimming, the cleansing, and the Yorkshire stone square. Each of these different systems possesses certain characteristic advantages and disadvantages, but all produce beers of varying quality.

When fermentation is complete, the contents of the fermenting vats are allowed to remain quiet for a time, so that the yeast may settle out of the beer. The settled liquor is then either run off (as in the case of low-grade beers and stouts) into the trade casks; primed with a sugar solution, fined with a preparation of isinglass, and sent on to the market at once. In the case of higher quality beers it is run into casks, each of which contains about half a pound of the best hops (a process known as dry-hopping), taken to a cool cellar and stored for several weeks or months, as may be necessary for the secondary or cask-fermentation which brings such types of beers into a condition suitable for drinking. When this is accomplished the casks are sent out; or their contents are bottled directly; or they may be chilled, filtered and bottled.

Composition and Analysis of Beers.

In an earlier portion of this article, the composition of wort was shown to be—malt-sugar, intermediate carbohydrates, dextrins, peptones, amides, other nitrogenous compounds and mineral salts or ash. After fermentation, the maltose, or much of it, will be found to have disappeared, being converted by the yeast chiefly into alcohol and carbonic acid gas, with small quantities of glycerin, succinic and other organic acids, and higher alcohols.

During the cask-fermentation in the cellars the intermediate carbohydrates of the beers gradually ferment away and bring the beverages into condition; consequently, the finished beers contain only dextrins, nitrogenous compounds and mineral salts, all of which form the extractive matters left after fermentation. These add to the palate-fulness and prevent the beers "drinking thin." They also are the bodies which may be looked upon as the nutrient constituents of the beverage. Owing to the comparatively large quantity of carbohydrate matters they contain, ranging from 3 to 15 per cent., malt liquors are the most nourishing of all alcoholic drinks; but the combined effects of alcohol, hop constituents and carbohydrates render them liable to produce obesity and a predisposition to gout, especially when taken in excess.

Beer Analysis.

The usual determinations undertaken in an analysis of a malt beverage are:—

1. *The original gravity*, which includes that of the present gravity, the percentage of alcohol, and the residue or extractive matters.
2. *The acidity*, which in new beer is derived from acid phosphates, and lactic or "fixed" acidity. In old beers there is also a quantity of acetic or volatile acidity due to the decomposition of alcohol by acetic bacteria.
3. *The opticity* and copper reducing power.
4. *The forcing tray*, or stability test.

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5. In addition, there are certain physical tests, such as the determination of colour, brightness, brilliancy, condition, amount and persistency of head, palate-fulness, etc.

The Different Malt Beverages

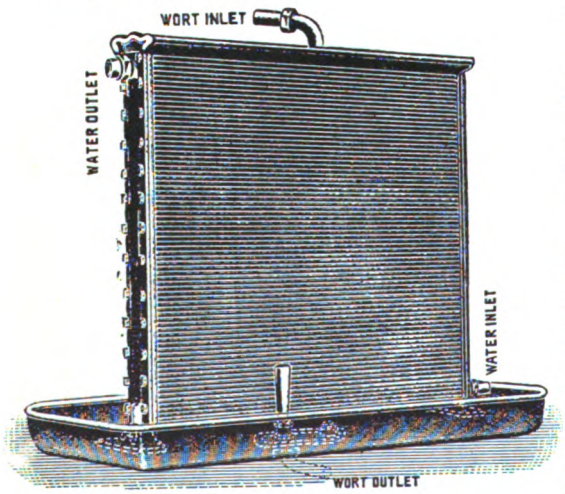
(English only).

Approximately, they may be classified as beers, ales, porters, and stouts.

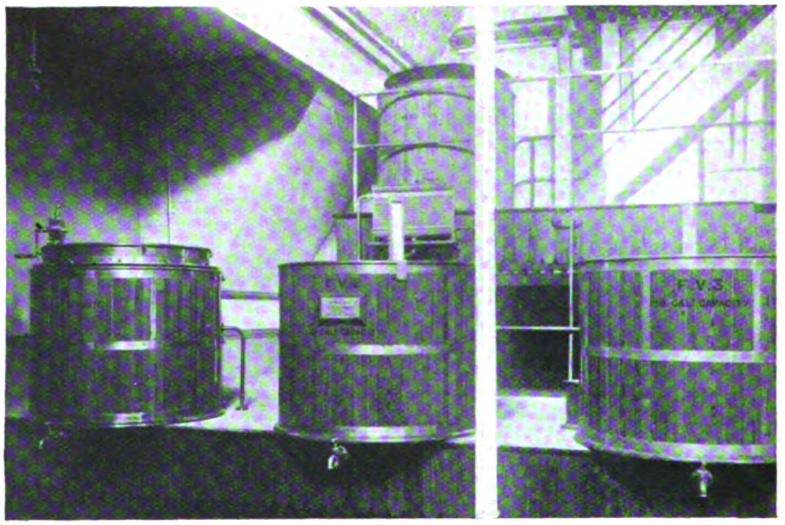
Ales and beers are further classed according to their composition and quality, as mild and running ales, bitters, strong beers, pale, export and East India ales.

At the present time, especially in the North, there is a tendency to use the terms ales and beers quite indiscriminately for either beverage.

A mild ale or beer is one prepared from highly-cured malt (frequently of a very inferior grade), much sugar or other malt substitute, and hops from four to seven pounds per quarter of grist.



Vertical Refrigerator for Cooling the Wort.



Fermenting Vessel in the Manchester School of Brewing.

Bitter beers contain rather more hops, averaging seven to twelve pounds per quarter.

In composition, the above beers contain about 4 per cent. of alcohol; extract about 6 per cent.; and acidity about 0·16 per cent.

Pale ales, *export beers*, and other higher-grade beverages are brewed from a good quality of low-cured malts, and from ten to seventeen pounds of hops per quarter.

In composition, they contain alcohol 6 to 9 per cent.; extract 6 to 15 per cent.; and acidity 0·2 to 0·5 per cent.

Porter is a black beer, originally brewed (for the London porters) in deep coppers, so as to obtain a high boiling temperature. Ordinary highly-cured malts, substitutes, caramelised malt and sugars, and hops are used in its preparation. The name is often applied to low-grade stouts.

Stout, a black beer of varying type, brewed from rather better materials than porter, and hopped according to gravity from six to sixteen pounds per quarter of grist. Composition: alcohol, from 4 to 8 or 9 per cent.; extract 4 to 15 per cent., and acidity from 0·35 to 1·50 per cent.

In addition to the above beverages, almost every brewery has its own special star ale and invalid stout, while many cottagers and small brewers prepare a home-brewed beer of doubtful quality and taste.

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GLOSSARY OF BREWING TERMS.

Alcohol.—The generic name of a numerous group of organic compounds composed of carbon, hydrogen, and oxygen. In brewing, the term indicates ethyl alcohol or spirits of wine.

Alkaloids.—A group of complex nitrogenous bases, which possess an alkaline reaction, and for the most part are both bitter and poisonous. Those in hops are extremely bitter.

Attenuation.—Term applied to worts during the fermentation in which they lose wort-sugars and become alcoholic, and hence thinner or attenuated.

Attemperators.—A system of pipes, through which cold water may be passed, fixed in fermentation and other vessels, to enable temperatures to be lowered or controlled.

Albumenoids.—Very complex nitrogenous substances existing in the vegetable and animal kingdoms.

Burtonising.—The act of adding mineral salts to water, to cause the liquid to resemble that found in the wells and springs around Burton-on-Trent. It is also known as "hardening."

Coppers.—Vessels used in breweries for boiling worts with hops.

Cooler.—A rectangular shallow vessel, fixed in an airy position in the brewery to permit of worts being aerated as well as cooled.

Converter.—A steam vessel used for gelatinising starchy materials such as grits or raw grain.

Cask-fermentation.—A secondary or after-fermentation which takes place in casks in the brewery cellars.

Carbohydrates.—A very important group of organic compounds, composed of carbon and the elements of water, which exist chiefly in the vegetable kingdom. The more common are:—the starches, sugars, dextrins, celluloses, and gums.

Dextrins.—A group of unfermentable carbohydrates which assist in giving palate-fulness to beers.

Dressing.—Occasionally fermentation becomes sluggish. To aid it, substances such as malt-flour and salt, ordinary flour and salt, etc., are added to the contents of the fermenting vats. This is "dressing" the fermenting gyle.

Diastase.—A soluble ferment or enzyme which converts starch into sugars.

Dry-hopping.—The placing of dry hops in casks into which beer is brought to mature and condition; also known as "hopping-down."

Essential oils.—Mixtures of closely related compounds of an aromatic character, composed of hydro-carbons, alcohols, or ketones of the terpene and camphor groups; known as the sweet-smelling oils of plants. Those of hops confer both flavour and aroma on the beers.

Fermentation.—A boiling or bubbling up. In brewing, the decomposition of wort sugars into alcohol, carbon dioxide, and small quantities of other bodies. The carbonic acid causes the bubbling, hence the name. Fermentation is brought about by the life-action of yeasts and other micro-organisms. (*See* TECHNICS, February and March.) The work is carried out in deep circular or rectangular vessels, known as the fermenting vats.

Fining.—The process of clarifying beers, wines, etc., by means of a preparation of isinglass.

Fusel oils.—Name given to a group of higher alcohols which occur in small quantities in fermented liquids.

Grist.—Name given to the crushed malt, sugars, flakes, etc., used in the preparation of worts.

Goods.—The contents of the mash-tun during the brewing operation of mashing are designated "the goods."

Goods' heat.—The temperature of the mash-tun contents during the "stand-on."

Grains.—The solid portion of the goods in the mash-tun, while the liquid is the wort.

Grinding.—The process of crushing the malted grain ready for mashing.

Gums.—A group of organic bodies of a carbohydrate nature which exist in both animal and vegetable life.

Grading.—The operation of separating the barley and malt corns into different sizes.

Hops.—The female catkins or cones of the *Humulus lupulus*, used for flavouring, scenting, and preserving beers. The chief constituents are essential oils, resins, tannins, and alkaloids. After boiling, the catkins act as a filter-bed for straining the wort.

Hop-back (*back*).—A vessel built of strong cast-iron plates capable of containing the whole contents of a copper. It possesses a perforated false bottom, on which the hop-cones rest, and thus they become a filter-bed for the wort.

Initial heat.—The temperature of the mixture of water and grist on completion of the mashing.

Isinglass.—Prepared skins of the swimming bladder of the hake and similar fish, a preparation of which is used for clarifying beers, wines, jellies, etc.

Liquor.—The name given to water when used in brewery operations.

Liquor-heat.—The temperature of the water used for mashing and sparging.

Malt.—The product obtained by germinating cereals, especially barley, under starvation conditions. The green malt is afterwards dried and cured.

Mashing.—The operation of mixing the grist with water of a suitable temperature, either by means of an external mashing machine, or by rakes in the mash-tun.

Mash-tun (*tub*).—The vessel used for containing the mash during the "stand-on" and sparging operations.

Priming.—The addition of sugar solutions to beers in casks to assist in the secondary fermentation.

Proteids.—Name given to certain amorphous substances composing the solid constituents of

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animal tissues, plant-cells, and other products of animal and plant-life. They consist of carbon, hydrogen, nitrogen, oxygen, and sulphur in combination.

Racking.—The operation of drawing off beers into either the trade or store casks.

Resins.—Complex aromatic, organic substances, which are obtained chiefly from plants belonging to the Conifera.

Refrigerator.—A vessel employed for cooling down worts to a temperature suitable for the addition of yeasts.

Sparge.—An arrangement of revolving arms through which water flows: used for washing out the extract from the grains in the mash-tun, and from the spent hops in the hop-back.

Stand-on.—After mashing the "goods" are allowed to stand for about two hours in the mash-tun to enable the diastase to convert the starch of the grist into sugars. This is "standing-on."

Striking.—The mixing of the hot liquor with the grist in the operation of mashing.

Sugars.—A very important group of carbohydrates, which exist in both the vegetable and animal kingdom. They form a food for plant and animal, as they are crystallizable, soluble, and diffusible.

Tannins.—A numerous group of organic bodies possessing bitter and astringent properties. They exist largely in the vegetable world, and are the active constituents of substances used for tanning skins. Two at least of the tannins are present in hop cones.

Tap heats.—The temperatures at which worts are drawn off from the mash-tun.

Turning-out.—The process of running off the contents of the brewing coppers.

Wort.—The saccharine or sugar solution obtained by the process of mashing.

LECTURE NOTES AND HOME EXERCISES.

By FRANCIS C. FORTH, Assoc. R.C.Sc.I., Principal of the Municipal Technical Institute, Belfast.

IT is generally conceded that students should prepare and retain a written record, more or less complete according to circumstances, of the instruction given at lectures. In addition, the majority of teachers of science and technical subjects consider it desirable that some time outside class hours should be devoted to answering questions and working out calculations: this is particularly desirable in the case of evening classes, since there the teacher, as a rule, has an all too limited time at his disposal for imparting instruction, and consequently every lesson, if it is to be thoroughly effective, must be reinforced by strenuous effort at home on the part of the student. This home work should be executed on some plan possessing the merit of being at once systematic, convenient for the student, and admitting of ready checking and verification by the teacher.

The method commonly used does not lend itself to a satisfactory solution of the last-named condition, *viz.*, the preservation of the notes in a form which can be readily examined by the teacher with the minimum of inconvenience. The practice pursued in many evening classes is somewhat as follows:—The student takes down notes of the instruction given in a book, which may be of a pattern adopted generally throughout the institute, or, where no regulation as to pattern exists, the book may be of any size or shape. At the conclusion of the lesson, it is usual to set exercises which the students are expected to work at home, where also such notes as possess a permanent value are transferred by the student from his rough notebook into a book of more enduring form. At the next meeting of the class the exercise book is handed to the teacher, who gives the student a fresh set of home exercises, which, with the accompanying notes, are then entered in a second book. This latter book is handed to the teacher at the succeeding lesson, when the first book is returned, corrected, to the student. If a student attends classes in a number of subjects, he requires a couple of home work books for each; thus the number of books he requires may become inconveniently large. An obvious disadvantage arising from this alternation of home work books is that, as the notes of lessons are not consecutively arranged, they are, as a consequence, unfavourably placed for ready reference.

It is customary for teachers to insist upon a specified pattern and size of book being used for home exercises; should no regulation exist upon this point, the difficulties of the teacher are much increased, owing to the miscellaneous assortment of books that are handed in. As to the use of books at all, various objections exist. Evening students who are compelled to proceed direct from work to their class, owing to lack of time to go home, find that books are troublesome to carry, the result being that the

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worked exercises are often left at home. The teacher, too, finds the handling of a collection of thirty or forty such books no light matter; the mere carrying of them is a labour, whilst opening them at the proper pages in order to examine the work occupies a considerable time. Further, in the case of teachers who find only part employment at technical institutes, the home work books have either to be taken home by the teacher for examination and correction, or they are left at the institute, and the exercises checked at some time less convenient than could be chosen if the students' labours were at hand throughout the week.

The difficulties just detailed have made themselves markedly felt at the Municipal Technical Institute, Belfast, since its establishment in the year 1901; the resulting inconveniences became so great with the rapid increase in the number of students (now nearly 5,000), that at the beginning of the session 1903–1904 it was decided to adopt a uniform system of dealing with lecture notes and home work exercises in all classes which could be brought under a uniform system.

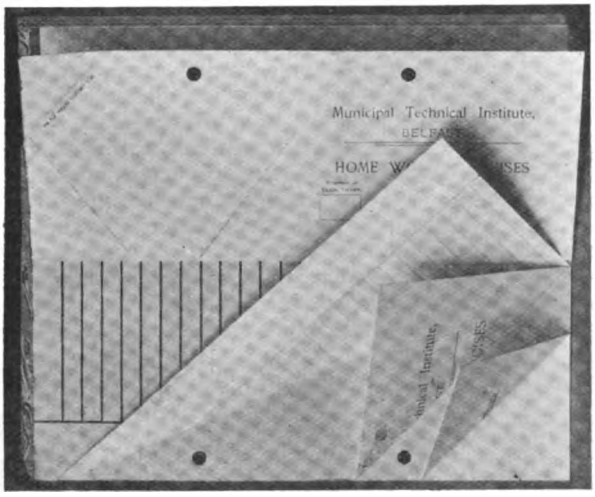

FIG. 1.—WRITING BLOCK.

As the plan followed has proved thoroughly satisfactory, it is thought that a brief account of the system may be of interest to the readers of TECHNICS.

With the object of obviating the disadvantages incidental to the use of books, it was decided to make use of some arrangement of separate, or at least easily detachable, sheets, provided that the drawbacks incidental to the use of loose sheets could be overcome. The first step was to obtain a quantity of blocks or pads resembling those used by artists. An illustration of one of these blocks is shown in Fig. 1. Some of the upper sheets have been folded over, the better to display the general arrangement. Each block is composed of 100 sheets of unruled paper, of a quality about equal to that of ordinary note paper. The sheets measure $8\frac{1}{4}'' \times 6\frac{7}{8}''$, a size of paper known to stationers at "lapost 6-mo." The sheets are glued together along the top edge, allowing them to be stripped off one at a time. The blocks are stiffened by a backing of strawboard. Students who find difficulty in keeping their writing equally spaced and in straight lines can place a ruled sheet supplied to them under the unruled page. If the home work exercise necessitates the making of a sketch, then lines might be inconvenient, and in that case the loose sheet is removed and the plain sheet is ready for sketching upon. As shown in the illustration, each sheet is punched with two holes, to enable it to be filed, in a manner explained later on.

The method of dealing with home work questions is as follows:—Each week the teacher sends to the office the draft of the questions which he purposes setting for his class. The number of copies specified by the teacher is then prepared, the typewriting machine being used for cutting a stencil, and the Neostyle for printing copies from this. The latter machine is rapid in its action, and enables the copies to be produced with the minimum of trouble and expense. It is calculated that the cost of stencil, typist's time, paper, ink, etc., averages about eightpence per set of home work papers prepared. The questions are printed on paper of the same size as the sheets of the blocks, and are punched with holes for filing purposes. At the ensuing lesson the questions are distributed amongst the class. By this method no time is lost in dictating questions, or writing them on the blackboard; and, moreover, the teacher is assured that the students have correct copies of all the examples.

When working exercises, the student commences on the top sheet of the block, stripping off each sheet when filled, and slipping the ruled leaf under the next sheet. Usually two or three sheets suffice for the questions set at any given lesson The exercises completed, the student pins the

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sheets together at the upper left-hand corner. The papers are then folded once, the student makes the requisite endorsement on the back of the last sheet used, and at the succeeding lesson hands his work to the teacher. Thus the teacher obtains from his class a small bundle of papers, resembling a number of sheets of notepaper. This bundle can be quite easily put into the breast pocket of the coat. When these papers have been examined and marked, they are returned to the student at the following lesson. The student is expected to take them home, and to file them in the manner now to be described.

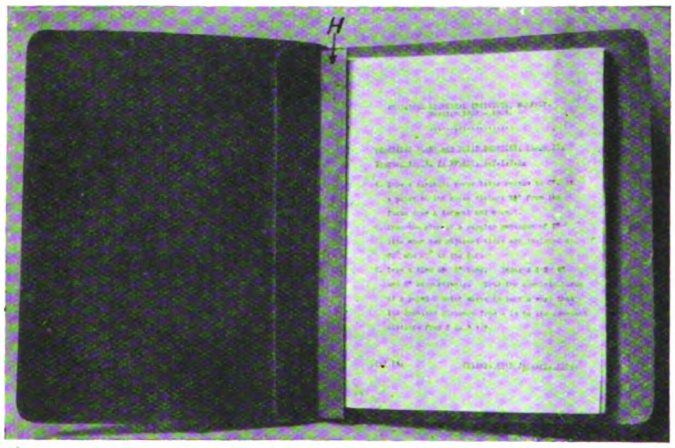

FIG. 2.—TO ILLUSTRATE METHOD OF FILING.

The filing cover used is shown in Figs. 2 and 3. The cover is made of stiff paper and has a hinge H (Fig. 2), to the back of which are secured two flexible metal pins P and P_1 (Fig. 3). The letters M M indicate a metal binding-piece, whilst G and G_1 are metal guards holding the pins flat against the binding-piece. The filing operation is exceedingly simple. The guards G and G_1 are slipped along the binding-piece in the directions shown by the arrows, when the pins can be bent upright and the binding-piece lifted off. Next, the sheets to be filed are turned face downwards and threaded on to the pins, the binding-piece is replaced, the pins bent outwards and downwards, and the guards slipped back into position so as to lock the pins: the whole operation takes only a few seconds. These files were made for us to a special size by the Stolzenberg Patent File Company.

The question of whether notes taken in class should be re-copied into a home work book is one on which some difference of opinion exists amongst teachers. On account of the time required, the practice of re-copying lecture notes is not encouraged at this institute. Students are advised to take their notes of lectures on the sheets of the block, and to subsequently file them, the order of filing for any given lesson being as follows: (1) Lecture notes; (2) home work question sheet; (3) worked exercises. This gives a complete history of each lesson.

The attachment of the sheets by this filing process is found quite satisfactory for all ordinary purposes. Of course, if a student at the close of a course of lectures desires to have his notes bound in regular book form, it is quite easy for him to have this done.

It was thought at first that the system, being an innovation, might not be taken up readily by teachers and students; but the convenience of the method has been so great that the students now like it very much, and the teachers are well satisfied with it. Looked at from the student's point of view, it will be seen that the purchase of one block at the opening of the session provides the necessary preliminary supply of paper for all the classes joined: formerly it was obligatory to buy two home work books for each subject, in addition to the general notebook, at the beginning of the course. From the teacher's point of view, the convenience of handling the papers is very great, and this in itself has sufficed to commend the system to the teaching staff.

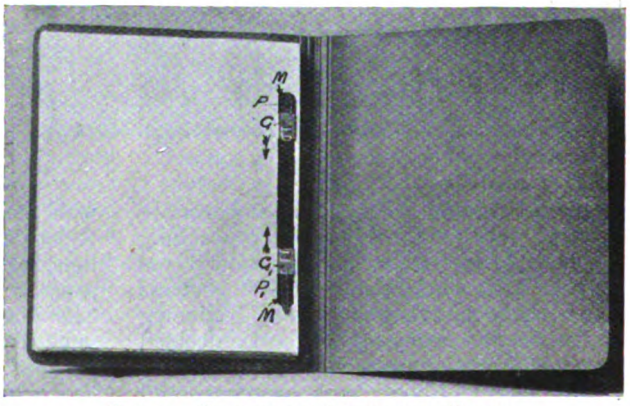

FIG. 3.—DETAILS OF METHOD OF FILING.

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THE CHEMICAL ANALYSIS OF HIGH-SPEED STEELS AND ALLOYS.

By FRED IBBOTSON, B.Sc. (Lond.), Joint Author of "Analysis of Steel-Works Materials."

CHAPTER III.

The Analysis of Alloys.

IN melting the materials for the manufacture of a steel, the required amounts of tungsten and chromium may be added in the form of tungsten powder mixed with ferro-chromium or metallic chromium. A more satisfactory and very commonly practised method, however, consists in the introduction of these elements in the form of a ferro-alloy, which may be made to furnish also the requisite amount of carbon, thus making it necessary to add only a suitable and calculable proportion of dead mild iron.

This chapter deals with the analysis of such alloys for carbon, tungsten, and chromium.

Determination of Carbon.

Two grams of the sample, passed through a 60-mesh sieve, are mixed with seven grams of red lead, and the mixture burnt exactly as described for steels. The aspiration should be carefully controlled until the temperature in the neighbourhood of the boat has reached that of redness, as the tendency to rushing is much more pronounced than in the case of steels.

When the boat is removed, the contents, with the exception of a few beads of metallic lead, are black in colour and should show signs of complete fusion. The author does not advise the use of the boat for a second determination, although he has frequently been fortunate enough to secure a duplicate determination without breakage.

Determination of Tungsten.

Many ferro-tungstens can be decomposed by treating them with a large excess of warm, but not boiling, hydrochloric acid, and then adding concentrated nitric acid a few drops at a time. Highly chromiferous alloys are much too refractory, however, and the following method, which is equally suitable for those which are free from chromium, gives very good results with alloys of all degrees of richness. One gram of the alloy, through a 60-mesh sieve, is placed in a deep and capacious platinum dish provided with a lid. From 10 to 15 cc. of hydrofluoric acid solution are then added, and the action accelerated by gently warming for no more than two minutes. The lid of the dish is then pushed aside slightly, and concentrated nitric acid added three or four drops at a time. After each addition a very vigorous action sets in, accompanied by much frothing and a copious evolution of nitrous fumes, thus making it necessary to push the lid smartly back into position and to wait for at least a minute between each addition of the nitric acid. When the addition of the nitric acid causes no further audible action (a condition which is frequently reached after the operation of adding the three or four drops has been repeated the same number of times), the alloy has gone completely into solution with the exception of a small carbonaceous residue. The dark green solution is then allowed to digest for five minutes, and then 5 to 10 cc. of concentrated sulphuric acid are cautiously added in drops, the lid being pushed aside slightly for the purpose.

It is now permissible to evaporate the solution until thick fumes of sulphur trioxide escape, when the whole of the tungstic oxide will have separated. During the earlier stages of the evaporation there is a marked tendency to frothing, due apparently to the decomposition of the carbonaceous residue left unattacked by the mixture of hydrofluoric and nitric acids. It is therefore advisable to exercise considerable vigilance until this stage has been passed. The subsequent evaporation may be hastened by heating over a rose burner, but the lid of the dish should not be removed during the process.

When copious fumes of sulphur trioxide escape, the evaporation is stopped, and, after cooling the dish, 10 cc. of hydrochloric acid are very cautiously added, and then an equal quantity of water. The mixture is warmed for a few minutes, and the whole mass then transferred by means of the wash bottle to a capacious beaker. Except for an obstinate iridescent film on the sides and bottom of the dish, the "policeman" effectually removes the whole of the insoluble residue.

The bulk of the liquid in the beaker is made up, if necessary, to about 100 cc. with

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distilled water, the whole brought to boiling, and maintained in ebullition for five minutes.

In the meantime a pulp filter should be prepared, on which the tungstic oxide is collected after allowing a short time for settling. The precipitate is washed with hot water slightly acidulated with hydrochloric acid, and then transferred to the ignition dish or crucible.

A tiny piece of ashless filter paper soaked with one drop of ammonium hydrate will remove the film of tungstic oxide referred to above, and this can be ignited with the main precipitate.

After ignition, the mass of tungstic oxide is invariably discoloured by contamination with ferric and chromic oxides. The amounts of these depend on many circumstances, such as, for instance, the richness of the alloy and the rate at which the preliminary "opening out" and subsequent evaporation have been conducted. Amounts varying from one centigram of ferric oxide associated with two milligrams of chromic oxide, to as much as eight times each of these quantities, have been found by the author.

The ferric and chromic oxides are determined precisely as described under the determination of tungsten in steel.*

Determination of Chromium.

One gram of the alloy, which has been passed through a 90-mesh sieve and subsequently agate-ground, is mixed in a capacious nickel crucible with at least five times its weight of sodium peroxide.† The crucible, without its lid, is grasped tightly by a pair of tongs and held in the upper part of the Bunsen flame. A vigorous action may suddenly set in, particularly if the peroxide is taken from a freshly-opened canister; consequently, unless due care is exercised, there is a liability to loss by projection. Very often, however, the mass quietly melts, and as soon as it is possible to impart a rotary movement to the contents, the crucible is held lower in the flame, so that a visible but pronounced red heat is attained for at least one inch up the crucible. The liquid mass is kept in constant and rapid rotation for about three minutes, after which the crucible is removed from the flame and kept moving until the contents solidify. The decomposition of the alloy is now completed.

As many as twenty fusions may be got from one and the same nickel crucible by conducting fusions with sodium peroxide in the manner just described.

When the crucible is cold enough to be handled, it is placed in a capacious beaker, and warm water added in quantity sufficient to cover it. The "melt" rapidly comes away, and when the expulsion of oxygen has almost ceased the crucible is removed by means of a glass rod and well washed inside and out.

It is not necessary to wash with warm water until the washings no longer bring away black nickel oxide with them; this would overtax the patience of any chemist.

The whole extract is now transferred to a graduated flask of 500cc. capacity and made up to the mark with water. The temperature is taken, and the contents of the flask are then emptied into a large beaker to allow the insoluble oxides of iron and nickel to settle. An asbestos filter is then made from the dry ignited material, using the supernatant yellow liquid for the purpose; 250cc. of this are then poured through, due correction being made for the temperature. The residue of insoluble oxides is treated with an excess of hydrochloric acid and the mixture heated to effect complete solution. The presence of fine, heavy metallic particles at the bottom of the beaker shows that the initial decomposition of the alloy with peroxide was incomplete, and a fresh assay should be started at once. If no such particles are visible, this solution can be rejected and the determination proceeded with.

The filtrate in the 250cc. flask contains the chromium and tungsten as sodium chromate and tungstate respectively. It is transferred to a beaker or large flask and boiled vigorously for a few minutes to decompose the last traces of hydrogen peroxide and then acidified with dilute sulphuric acid. This may result in the partial separation of the tungsten as tungstic oxide, but occasions no inconvenience during the subsequent determination of the chromium. The latter operation is conducted in the usual manner by adding an excess of ferrous-ammonium sulphate solution (acidified with sulphuric acid) and titrating the excess of ferrous iron by means of a standard solution of potassium

* 50cc. of a decinormal ferrous solution can reduce an amount of chromic acid corresponding to 0·0868 grams metallic chromium; hence this volume of ferrous solution (50cc.) is sufficient for alloys containing up to 17·36 per cent. of chromium.

† Instead of fusing 1 gram of alloy and resorting to fractional filtration, half this amount of alloy can be operated upon, and after boiling out with water, and expelling all traces of oxygen, the whole extract is treated with dilute sulphuric acid until the oxides of iron and nickel are taken completely into solution.

The author considers that this method consumes rather more time than the one described above.

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bichromate, using the spot test with potassium ferricyanide to determine the end of the reaction.

CHAPTER IV.

The Determination of Minor Constituents, etc.

It is occasionally necessary to determine sulphur, phosphorus and manganese in self-hard steels and alloys, so that, whilst avoiding a description of methods with which all steel analysts are familiar, the few following paragraphs may be found useful.

"*Opening-out*" *Alloys.*—The decomposition of a high-speed steel with aqua regia is readily accomplished, and after removal of the tungsten and silicon, the filtrate readily lends itself to the determination of sulphur, phosphorus, and manganese. In the case of an alloy rich in tungsten and chromium, however, the attack of a mixture of nitric and hydrochloric acids is not so satisfactory, and a casual inspection of the result of a digestion with these acids for an hour might lead one to reject the assay. Nevertheless, success may be obtained by attention to the following particulars (*Cp. Jervis, Chemical News*, 86, 272).

To 2·5 grams of the alloy, in a tall beaker, add 20 cc. of nitric acid (s.g. 1·42), and then, in small quantities at a time, 25 cc. of concentrated hydrochloric acid. When the action subsides, add a few crystals of potassium nitrate and apply a gentle heat with the cover glass in position. The mixture must not be heated to boiling; this would create bumping and also defeat the object in view by weakening the acids. Protracted digestion below a boiling temperature results in very little evaporation, and the alloy is slowly but surely decomposed. If the heat is applied continuously for 24 to 30 hours, a yellow residue of tungstic oxide results; a green colour represents imperfect decomposition. The liquid may now be evaporated to low bulk, diluted, the residue filtered off, and the filtrate suitably dealt with for the determination of sulphur, phosphorus, and manganese.

Since it is obviously inadmissible to use the rapid method of decomposing these alloys with a mixture of hydrofluoric and nitric acids when a determination of sulphur (or of molydenum) is required, the above method, although tedious, is very useful, particularly as an opening out with sodium peroxide necessitates "blank" determinations, and is in other respects somewhat objectionable.

Ferro-Chromium and Tungsten Powder.—The chromium and tungsten of a self-hard steel or alloy are furnished by ferro-chromium (or metallic chromium) and tungsten powder respectively, so that a few remarks concerning the analysis of these may fittingly be made in concluding these articles.

Concerning ferro-chromiums, the two essential elements for determination are carbon and chromium; the amount of the former is often very considerable, and therefore materially influences the percentage of this all-important element in the alloy or steel. One gram of the ferro-chromium, through a 90-mesh sieve, is mixed with five grams of red lead, and the mixture spread along the bottom of a boat previously lined with asbestos. The air current should be aspirated for a full hour after the highest possible temperature of the furnace has been reached. The temperature in the neighbourhood of the boat should be raised as gradually as possible, in order to avoid a violent evolution of carbon dioxide. A fused mass of lead chromate remains in the boat.

The chromium is determined on half a gram of the finely divided sample exactly as described in Chapter III., using the peroxide fusion method. A bichromate solution of decinormal strength is too weak for the titration, however, and one of about three times the strength should be used.

With respect to tungsten powders, it is also necessary to determine the carbon contents. The amount of this element varies very much, and it often exists, even in high-class samples, in the form of charcoal. For a determination, several grams of the alloy, unmixed with red lead, are burnt in a stream of air at a red heat.

The *total* tungsten, metallic and oxidised, is easily determined by the method already described for this element in Chapter III. There is, of course, no correction to be made for the presence of chromium. An approximate determination of the amount of tungsten existing as sodium tungstate and tungstic oxide can be made by boiling a sample of the powder with a weak solution of sodium hydrate. The filtrate, after acidification with hydrochloric acid, is then evaporated to separate the tungstic oxide and the assay finished as usual. Information of quite as reliable a character concerning the richness of a tungsten powder is yielded by a careful determination of its specific gravity.

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART II.—TUBES OF FORCE IN MOTION.

By EDWIN EDSER, A.R.C.Sc.

IN the October number of TECHNICS I discussed briefly the properties of tubes of force at rest. It was there shown that each tube of force has a tendency to contract longitudinally, and to expand laterally. Further, it was pointed out that what we call "electricity" may be looked upon as corresponding to the ends of tubes of force, positive electricity corresponding to the ends of tubes where they *leave* matter, and negative electricity to the ends of tubes where they *enter* matter. Attention must now be directed to the explanation of the electric current. When a charged electrical condenser is discharged through a galvanometer, the swing of the galvanometer needle indicates that an electric current passes. Since the result is the same, whether the condenser is charged electrostatically, by the aid of a Wimshurst machine, or voltaically, by the aid of a cell or battery, we must conclude that the electric current involves the motion of electricity of the same character as that produced by rubbing two insulated bodies together. A further obvious inference is that, associated with the electric current, there must be motion of electric tubes of force.

It may be as well to review briefly the properties of the electric current. In the first place, heat is produced in conductors through which an electric current flows; in other words, we may infer that the electric current, when flowing through a conductor, sets the molecules of the conductor in more rapid motion. This fact has led to a very general belief that electricity is forced along a conductor, somewhat as water may be forced along a pipe. . . . . When an electric current flows through a solution, some sort of chemical decomposition occurs; Faraday proved that the rate at which the chemical decomposition proceeds is proportional to the current. . . . . When an electric current flows along a conductor, a magnetic field is formed in the surrounding space. This is the fundamental property on which measurements of the electric current are based.

If we regard the electric current as the motion of some sort of fluid through the interior of a conducting wire, it is easy to account for the production of heat in the wire. When water flows along a pipe, some of the energy of the water is dissipated in the form of heat; if the pipe is everywhere uniform in section, the pressure of the water falls in the direction of flow, just as the "electrical pressure" or "potential" falls along a wire in the direction of the current. The waste of energy in the electric circuit is of so much practical importance, that there is a tendency to concentrate our attention on this, and to rest satisfied with a theory which gives a simple explanation of it; but it is easily seen that this procedure is illogical in the extreme. The electrical resistance of a conductor depends on its length, its sectional area, its temperature, the metal or alloy from which it is made, and even on the past history of the metal or alloy; consequently the dissipation of energy in the form of heat in a conductor, though of the greatest practical importance, is not a phenomenon which is likely to indicate the fundamental nature of the electric current. For similar reasons the chemical effects of the electric current offer no very certain base on which to erect a theory. The phenomenon which is invariably associated with the electric current, and depends on that alone, is the magnetic field in its neighbourhood. This cannot be explained by considering the electric current to be a stream of fluid passing along the conducting wires: any theory involving merely the motion of a fluid through a conductor can give no explanation of phenomena produced outside the conductor.

Before finally dismissing the fluid theory of electricity, it may be as well to show that it is inconsistent with the results of various experiments. When a fluid passes from a wide to a narrower section of pipe, the pressure falls; conversely, when the flow occurs from a narrow to a wider section of the pipe, the pressure rises. This result exemplifies the well-known law of fluid motion—"where the velocity is greatest, the pressure is least."

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Now there is no parallel phenomenon in connection with the electric circuit. If a wire becomes thinner to a certain point, and then becomes thicker, the "pressure" of the electric current *falls all along the wire:* the rate of fall of pressure is greatest where the wire is thin, but there is no indication of a rise of pressure as we proceed from a thin to a thicker part of the wire. This fact alone is sufficient to dispose of the fluid theory of electricity.

A further disproof of the fluid theory was furnished by Maxwell. Let us suppose a pipe to be formed into any number of circular turns, the ends being bent back to the centre of the circle (Fig. 1), so that a fluid can flow from the centre to the circumference, then round the circumference, and finally back to the centre of the circle. If the flow occurs in the direction of the arrows (Fig. 1), it is plain that at A the fluid acquires momentum tangential to the circle, in the direction of flow round the circumference. The reaction due to the tangential momentum imparted to the fluid at A will tend to turn the tube about the centre, C, in an anti-clockwise direction. Similar reasoning shows that the destruction of the tangential momentum of the fluid at B will generate a reaction tending to turn the tube in a clockwise direction about C. When the flow is steady, the reactions at A and B neutralise each other, so that there is no tendency for the tube to turn about C; but on starting the flow, the reaction at A is for a short time unneutralised, since it occurs before the reaction at B is produced. When the flow stops, the reaction at B occurs after that at A has ceased. Consequently, on starting the flow, the tube tends for a moment to "kick" in a direction opposite to that of the tangential flow; while, on stopping, a momentary "kick" in the direction of the tangential flow occurs.

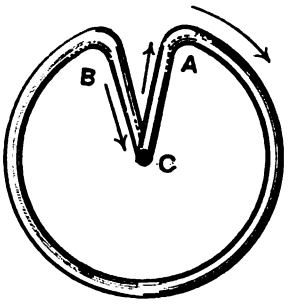

FIG. 1.

To find whether a similar effect is produced by the electric current, Maxwell suspended a coil of fine wire (Fig. 2) with its axis vertical. The suspending wire served to convey the current into the coil, while another wire, hanging downwards and dipping into mercury, served to convey the current away. A small mirror was attached above the coil, and a scale reflected in it was observed by the aid of a telescope, so that any rotation of the coil could be readily observed. On making and breaking the electrical circuit, there was no trace of a "kick" by the coil, thus showing that the electric current does not involve the flow along the wires of a fluid possessing inertia.

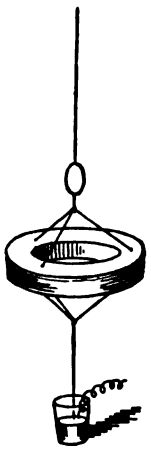
FIG. 2.

Other experiments, however, indicate that a considerable amount of inertia is, in certain circumstances, associated with the electric current. On closing a circuit comprising a battery and a coil of many turns of wire, the current does not at once rise to its final value; and on breaking the same circuit, the tendency of the current to continue its flow is so pronounced, that a spark may be produced, indicating an electrical pressure many thousand times greater than that of the battery. Mechanical analogies of these phenomena will readily occur to the reader. The application of a given driving torque to a fly-wheel will not at once cause the latter to acquire its final velocity; and the very sudden stoppage of the fly-wheel would require the application of a resisting torque much greater than the original driving torque. If a water-tap is suddenly closed during the full flow of the water, the sudden stoppage of the water in the pipe may produce a pressure sufficient to burst the pipe. This last-mentioned phenomenon at first appears to be closely analogous to the formation of a spark on breaking an electric circuit, but there is one important difference. The inertia of the water depends merely on the length and sectional area of the pipe, that is, on the quantity of water set in motion. Whether the pipe be straight, or wound into a coil, or even folded back on itself, makes no difference to the inertia of the contained water. The inertia associated with the electric current is practically independent of the sectional area of the conducting wire; although it is in general increased by increasing the length of the wire, it depends mostly on the way in which the wire is arranged, being increased when the wire is wound into a coil, and diminished almost to nothing when the wire is folded back on itself. If a core of soft iron is introduced into a coil of wire, the inertia of the current flowing through the coil is enormously increased. All of these facts

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indicate that the inertia associated with the electric current is not due to anything flowing along the wires, *but to something set in motion in the space surrounding the wires.* When we remember that electricity may be regarded as the ends of electric tubes of force, and that these tubes extend through the space surrounding a conductor, it becomes probable that it is the electric tubes which are the seat of inertia. If this be true, a tube of force can only be set in motion by the expenditure of energy; and when in motion, it can perform work on any body which stops it.

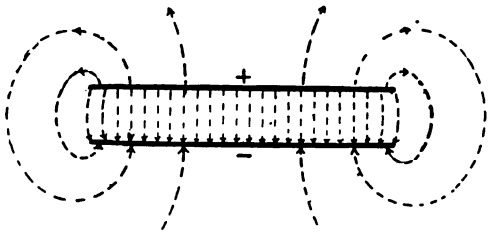

FIG. 3.

It now becomes advisable to study the motions of the electric tubes of force under the simplest possible conditions, as for instance, when a plane condenser is discharged through a perfectly conducting circuit. A plane condenser consists of two flat conducting plates placed parallel to each other at a small distance apart; for simplicity it will be assumed that there is no material medium other than air between the plates. If the upper plate receives a (+) charge, while the lower plate receives an equal (−) charge, the distribution of the lines of force will be similar to that represented in Fig. 3. Between the plates, and at a reasonable distance from their edges, the lines are straight and parallel, extending from the upper to the lower plate: the lines must leave or enter a plate normally, since the plates are conductors, and they are forced to remain parallel to one another by their mutual lateral repulsions. Only a few lines start from the upper surface of the upper plate, and curve round to enter the lower surface of the lower plate; the longitudinal tension of the lines causes the great majority of them to squeeze into the space between the plates, so that they may contract to the shortest possible length. The lateral repulsion between the lines causes those which lie near the edge of the condenser to curve slightly outwards.

If we connect the plates by a conducting circuit, as indicated in Fig. 4, some of the tube ends are forced on to the wires, and set in motion along them. If the wires are perfect conductors, they will offer no resistance to the motion of the ends of the tubes of force along them, and accordingly the tubes will leave and enter the wires normally; those in the plane of the conducting circuit will stretch straight across from the upper to the lower wire, and *their direction of motion must therefore be perpendicular to their lengths.*

In accordance with the experimental evidence already discussed, we must suppose that each tube of force, when moving perpendicular to its length, possesses a certain amount of kinetic energy, or is endowed with inertia. When once set in motion, a tube will travel through the space between the wires till it reaches the connection between the upper and lower wires, at which point its longitudinal tension will cause it to contract. Now if the wires are perfect conductors, no energy can be lost by a tube as its ends travel along them; consequently, when the tube shrinks to indefinitely small dimensions at the junction of the two wires, it cannot become annihilated, since this would involve the disappearance of both the potential energy due to the contractility of the tube, and the kinetic energy due to its velocity of motion. It will be proved later on that the energy per unit length of a tube of force, whether potential or kinetic, is inversely proportional to the sectional area of the tube; consequently the tube, as it contracts in length, must shrink in area at a proportional rate. The two ends of the tube travel towards each other at a constant velocity, and finally pass each other; with the result that the tube subsequently increases in length and sectional area, and finally travels back toward the condenser, extending now from the lower to the upper wire.

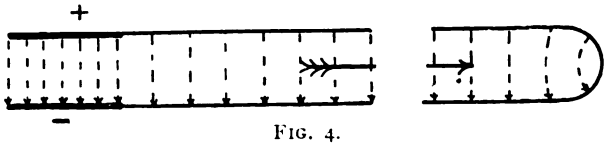

FIG. 4.

If the reasoning just used is correct, each tube of force, after leaving the condenser, travels along to the end of the conducting circuit, where its direction becomes reversed; it then travels back to the condenser. It is easily seen that after a certain time every tube, after its direction has been reversed, will have returned to the condenser, so that the charge of the latter will have become

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reversed. After remaining stationary for an instant, the tubes will once more be projected along the conducting circuit, to again become reversed; they then return to the condenser, which thus regains its original charge. This process would continue indefinitely if the wires were perfect conductors, just as a pendulum would go on swinging to and fro

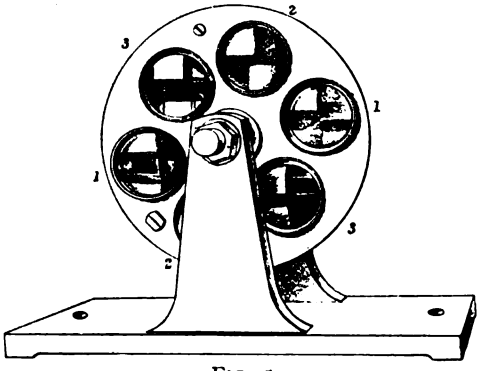

FIG. 5.

for ever, in the absence of friction and other sources of dissipation of energy. In practice perfect conductors cannot be obtained; but we may infer that if the circuit is so arranged that the length of the moving tubes of force is considerable, so that their kinetic energy may be great, while the conductivity of the wires is as great as possible, then we shall obtain an oscillatory discharge resembling that described above, but lasting only for a limited time.

The oscillatory nature of the discharge of a condenser was first predicted by Lord Kelvin; it was afterwards experimentally verified by Feddersen, who provided a small spark gap in the circuit, and examined the spark by the aid of a rotating mirror. A more convenient method of investigation was invented by Professor Boys.* A condenser was made of a number of plates of glass separated by sheets of tinfoil, the 1st, 3rd, 5th, 7th . . . . sheets being connected together to form one plate of the compound condenser, the 2nd, 4th, 6th . . . . sheets being connected to form the other plate of the condenser. A large coil of insulated thick copper wire was included in the connecting circuit, in order to give sufficient length to the moving tubes of force; a spark gap, consisting of two bright metal knobs, was also included, and an image of the spark was projected on a photographic plate by the aid of a series of lenses mounted in a disc capable of being rotated at a high speed (Fig. 5). Six lenses were used, those marked 1, 1 being at opposite ends of a diameter, and a tenth of an inch further away from the axis of rotation than those marked 2, 2, while these latter lenses were a tenth of an inch further from the axis than those marked 3, 3. The disc was caused to revolve, and the images of the spark were projected on a photographic plate; if the spark produced only an instantaneous illumination, six separate images of the spark would be formed on the plate; while if the spark were intermittent, indicating an oscillatory discharge, each of the six lenses would produce a circular band of bright images (one image for each discharge) separated by dark spaces. Fig. 6 shows the result actually observed, and proves conclusively that the discharge was oscillatory. Each component of the oscillatory spark takes the form of two luminous regions near the spark terminals, joined by a more feebly luminous space; this is due to the circumstance that incandescent particles are torn from off the metallic knobs forming the spark terminals, and the incandescence of each particle diminishes as it travels away from the point at which it was torn off. Fig. 6 shows the images of the spark at the beginning, middle, and end of the discharge formed by three of the lenses.

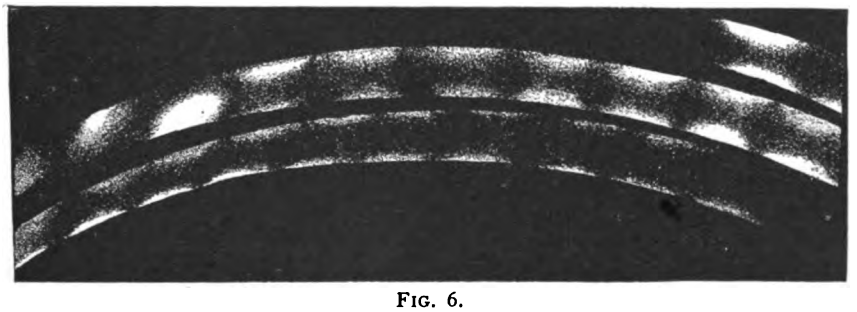

FIG. 6.

* Proceedings of the Physical Society, November, 1892.

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The images travelled over the plate in a clockwise direction.

If we now suppose the thick lines in Fig. 4, marked (+) and (−), to represent, not the plates of a charged condenser, but the (+) and (−) electrodes of a galvanic cell, then we should obtain a continuous discharge in place of the oscillatory one just discussed. In this case we may infer that a continuous stream of electric tubes of force, each extending from the upper to the lower wire, travels from left to right; while another stream of tubes, each extending from the lower to the upper wire, travels from right to left along the circuit. In this case no energy is lost in the conducting circuit, since the wires are perfect conductors; the whole of the energy carried away from the cell by the tubes moving from left to right is restored to the cell by the tubes travelling from right to left, and is finally dissipated within the cell itself. In the ordinary way of considering the problem, an "electric current" travels from left to right along the upper wire, and from right to left along the lower wire; consequently the magnetic lines of force will extend downwards through the paper, or a small magnet, mounted between the wires so that it is free to point in any direction, will turn so that its N. pole points downwards through the plane of the paper. The question now arises, can the production of a magnetic field in the space surrounding the wires be explained by the motion of the tubes of electric force?

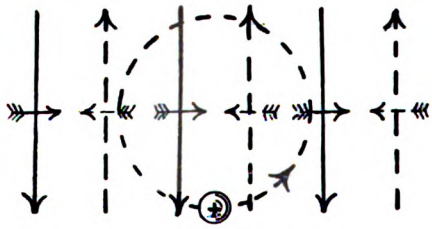

FIG. 7.

Experiments on the magnetisation of iron have indicated that each molecule of iron has properties similar to those of a small magnet; Professor Ewing's beautiful experiments illustrating this point are so well known that they need be no more than mentioned here.

Now, an electrically charged particle, when set in motion, will obviously carry its tubes of force with it, and will therefore be equivalent to an element of an electric current; if the particle moves in a circular orbit, its lines of magnetic force will be generally similar to those of a small circular electric circuit, or to a small magnet with its axis perpendicular to the plane of the orbit. Hence we may suppose that each molecule of iron acquires its magnetic properties by virtue of a charged particle revolving around it. Let us now suppose that a positively charged particle, revolving in an *anti-clockwise* direction in the plane of the paper, is placed between the two wires represented in Fig. 4; that is, the orbit of the particle lies in the same plane as the two streams of opposite tubes of force travelling in opposed directions. Now a positive charge, by definition, tends to move along the direction characteristic of a tube of force; but if the charge in question were stationary, the motion of equal numbers of opposite tubes of force across it would not cause it to move, since the forces due to the opposite tubes would neutralise each other. On the other hand, the positive charge, while moving from left to right on the lower side of its orbit (Fig. 7) will be moving *with* the tubes extending from above downwards, and *against* those extending from below upwards; consequently the number of tubes extending from above downwards that overtake and pass it will be less than the number of tubes extending from below upwards that it passes, with the result that the particle will be urged upwards, *i.e.*, in the direction of the tubes indicated by the broken line arrows. By similar reasoning, it is easily seen that the particle, while moving from right to left on the upper side of its orbit (Fig. 7), will be urged downwards, *i.e.*, in the direction of the tubes indicated by the unbroken line arrows. In this case the effect will be to make the orbit more or less elliptical, the major axis of the ellipse being horizontal. But if the orbit of the particle is inclined to the plane of the paper, as, for instance, if the particle moves above the plane of the paper in the lower part of its orbit, and below the plane of the paper in the upper part of its orbit, then the tendency will be to deflect the orbit about an horizontal axis, until it has been entirely turned over, so that its direction of rotation is now clockwise. It is easily seen that the orbit of a positively charged particle revolving in a *clockwise* direction between the wires in Fig. 4 will be stable, the effect of the moving tubes of force being to keep the orbit of the particle in that plane, or to pull the orbit, if originally inclined to that plane, into it.

Consequently, we may infer that if a piece of soft iron is placed between the wires in Fig. 4, the moving electric tubes of force will tend to deflect the axes of the magnetic molecules, so that all the revolving particles (if positively charged) describe orbits in a

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clockwise direction in the plane of the paper. But this is the fundamental property of a magnetic field extending downwards through the plane of the paper; hence we conclude that the motion of the electric tubes of force will account for the magnetic field between the wires. The characteristic of hard steel is that the axes of its magnetic molecules cannot be readily deflected; if the steel is permanently magnetised, then the axes of its molecules all point in one direction. It is obvious, therefore, that if a small magnetic needle is placed between the wires in Fig. 4, the hand wire being (+), and that of the right-hand wire (−). Now, let us suppose the electric tubes corresponding to these lines of force to be set in motion vertically downwards through the plane of the paper, while a set of similar but opposite tubes moves upwards through the plane of the paper. Each tube, of course, moves perpendicular to its length, and the magnetic field produced will be perpendicular to the tube and to its direction of motion. Thus, if we draw a series of curves in the plane of the paper, each cutting all of the electric lines of force at right angles,

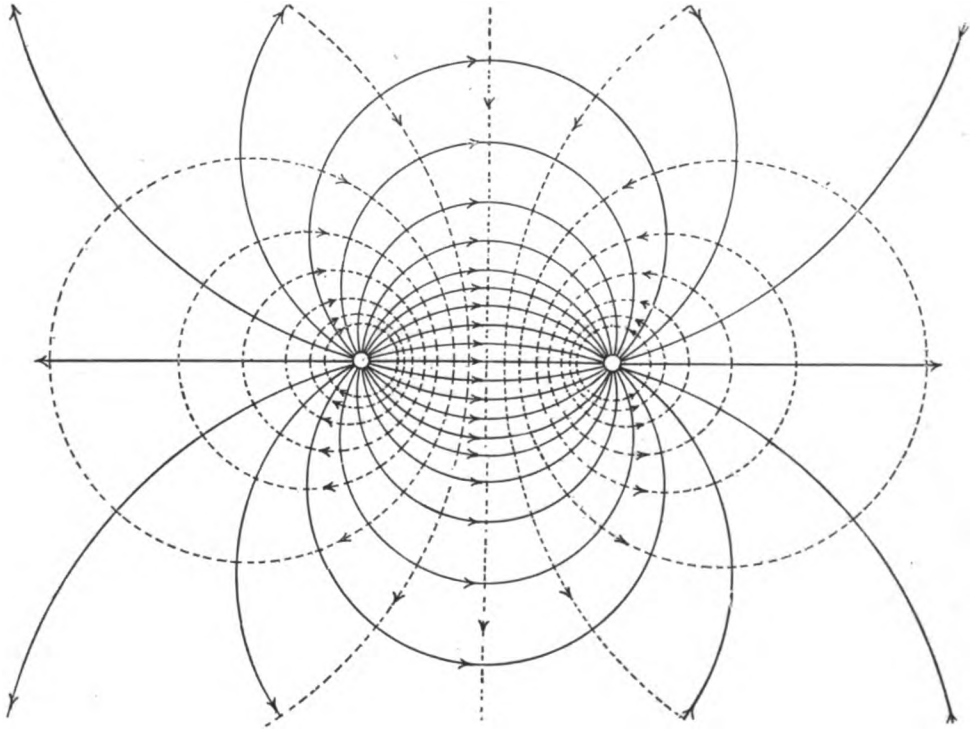

FIG. 8.

moving electric tubes of force will exert a torque on each magnetic molecule, tending to set its axis pointing vertically downwards through the paper; and as the molecules of the steel cannot move individually, a resultant torque is produced on the magnet as a whole, tending to direct its N. pole downwards through the plane of the paper.

We have, up to the present, considered merely the electric tubes of force extending in straight lines from one conducting wire to the other. In Fig. 8 the unbroken curved lines represent the lines of force extending between two charged wires perpendicular to the plane of the paper, the charge of the left-

the curves so drawn will represent the magnetic lines of force. The magnetic lines obtained in this manner are represented by broken curved lines in Fig. 8; they agree precisely with the magnetic lines observed experimentally.

Before concluding this article, two striking confirmations of the correctness of the conclusions arrived at may be mentioned.

If the electric tubes of force possess inertia, and therefore possess kinetic energy when moving perpendicular to their lengths, then the stoppage of the moving tubes of force by the right-hand end of the circuit in Fig. 4 must produce a reaction tending to move the end

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of the circuit to the right. That this reaction actually exists is proved by an experiment due to Ampère. In this experiment the end of the circuit is formed of a bent copper wire, the two ends of which are floated on mercury contained in parallel troughs (Fig. 9). When a battery is connected, by means of wires, to the two troughs, the copper wire bridge moves away from the end at which the connections are made. It will be easily understood why the force on the bridge is increased by increasing the distance between the troughs; the farther the troughs are apart, the greater is the length of the moving electric tubes of force, and therefore the greater is their inertia.

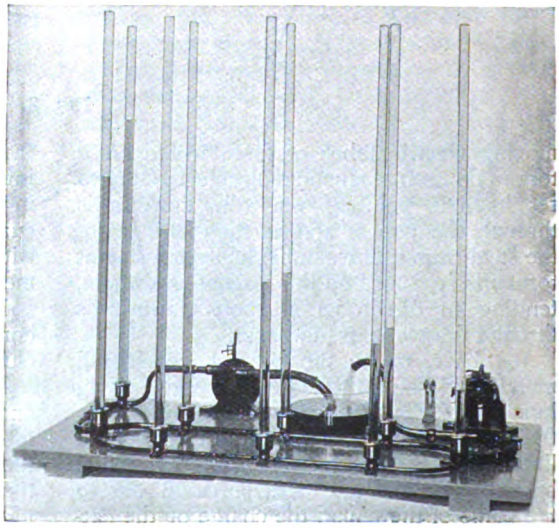
FIG. 9.

Rowland proved that when an electrically charged body is set in motion, a magnetic field is produced in its neighbourhood; the effect is obviously due to the motion of the electrical tubes of force associated with the charge. A circular disc of ebonite was gilt on one surface: radial cuts in the layer of gold divided this into a number of equal sectors. The disc was mounted on a vertical shaft, so that it could be rotated at a high speed about an axis passing through the centre, and perpendicular to the plane of the disc. Imagine the sectors to receive a (+) charge; then the tubes of force will extend vertically downwards below the disc and vertically upwards above the disc. The theory already explained indicates that, on rotating the disc, a magnetic field will be produced; the direction of the magnetic field should be radial, extending from the circumference to the centre below the disc, and from the centre to the circumference above the disc, if the disc is rotated in an anti-clockwise sense when viewed from above. Rowland's experiments indicated that such a magnetic field is actually produced; later Cremieu failed to confirm Rowland's observasions, until a source of error was detected by him in collaboration with Pender, who had previously assisted Rowland in his experiment. Thus it appears that the theory outlined in this article has received ample experimental confirmation.

(To be continued.)

HYDRAULIC MODEL OF THE ELECTRIC CIRCUIT.

WHEN water flows along a uniform pipe, the pressure falls from point to point exactly as the potential falls in the electric circuit. The pressure at any point in the pipe can be easily observed by inserting a vertical glass tube into which the water rises. Mr. C. A. West, B.Sc., has designed the very useful piece of lecture-apparatus illustrated herewith; this apparatus is made by the West London Scientific Apparatus Company, Deodar Road, Putney. A small centrifugal pump sucks water in from a beaker, drives it round a pipe circuit, and finally delivers it back to the beaker. A number of vertical glass tubes inserted in the pipe circuit show the way in which the pressure varies: the pressure is seen to be greatest where the water leaves the pump, and least where it returns to the beaker. Further, the rate of flow of the water is easily seen to be proportional to the pressure of the water where it leaves the pump. At one point the circuit is made up of two parallel branches, the pipes forming these branches differing in diameter; by this means the properties of the Wheatstone's bridge are clearly and simply exemplified.



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DR. CARTWRIGHT AND THE WOOL-COMBING INDUSTRY.

By ALDRED F. BARKER, Professor of Textile Industries, City of Bradford Technical College.

FIG. 1.—DR. EDMUND CARTWRIGHT.
(By permission of Messrs. Sampson Low, Marston, Searl and Rivington.)

THE life of Dr. Edmund Cartwright, whose work on behalf of the wool-combing industry has been so fittingly commemorated in Bradford—the centre of this industry—is full of interest and value, not simply to the student of the history of wool-combing, but to all interested in the industrial evolution of the past century. To make perfectly clear the influence of Dr. Cartwright on the industries of this country, more particularly on the combing industry, it will be well to consider his life under two heads :—

I.—Particulars of general interest concerning the several industries with which he was connected.

II.—Particulars of special interest on account of their bearings upon the evolution of the machine wool comb.

Edmund Cartwright was born on April 24th, 1743, being the fourth son of Wm. Cartwright, of Marnham, Nottingham, and Anne, daughter of George Cartwright, Esq., of Ossington. He attended the Wakefield Grammar School from 1753 to 1758, and it is recorded that he early manifested a tendency towards the Navy. Family influences, however, destined him for the Church. He matriculated at University College, Oxford, at 14 years of age, in 1757. He became Demy of Magdalen College in 1762, and Fellow in 1764. He does not seem to have held any college office, and was probably for the most part non-resident. He resigned his Fellowship on his marriage in 1772 to Alice, youngest daughter of Richard Whitaker, Esq., of Doncaster. He subsequently lived at Marnham Brampton, in Derbyshire, and Goadby Marwood, in Leicestershire. Having been a votary of the Muses at the early age of eighteen, he continued his literary pursuits; and between these, farming experiments, and curing his parishioners of putrid fever by copious doses of yeast, he seems to have passed through a very happy period of existence.

His commercial undertakings commenced at Doncaster in 1785, being based upon his invention of the power loom, which, by the way, included a warp-stop motion. It is interesting to note that at this period he was considered, by those moving in the same rank of society, to have deserted his caste. His commercial undertakings extended to Manchester, when, in 1791, Messrs. Grimshaw, of that city, ordered 400 looms, of which only 24 were delivered, the mill being burned down, no doubt deliberately. Thus his fortune was lost, and in 1793 he assigned his patents to his brothers, and in 1796 removed to London. His first wife having died in 1785, in 1790 he married Susannah, youngest daughter of the Rev. Dr. Kearney. His life in London seems to have been full of interest. Thus, in conjunction with Robert Fulton, he considered the question of steam navigation, submarine boats, etc., proposing the employment of his steam engines on Fulton's boats.

In 1798 he became a member of the Society of Arts, and was nearly elected

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Secretary. He received the silver medal of the Society of Arts between the years 1801 and 1807 for a three-furrowed plough, which he no doubt invented while farming on the Duke of Bedford's experimental farm at Woburn. He also received gold and silver medals from the Board of Agriculture in 1806, for an essay on the culture of potatoes; and being interested in the question of the chemistry of manures, he at this time was in communication with Sir Humphrey Davy. At the age of sixty-six, by means of the £10,000 granted by Parliament, he was enabled to retire to a small farm, Hollenden, in Kent, where he interested himself in his agricultural and mechanical inventions, at the same time being in communication with Mrs. Hemans, and developing a new theory of the planetary system. He died on October 30th, 1823, and was buried at Battle, in Sussex. The walls of the Abbey church bear a monument, upon which is recorded his life's work and certain of his verses. We, who can appreciate to the full—and still feel, as it were—the after-glow of his inspirations, would, however, prefer Lord Brougham's inscription to England's great engineer:—

"Not to perpetuate a name
which must endure while the peaceful arts flourish,
but to show
that mankind have learnt to honour those
who best deserve their gratitude."

We must all admit that it is well that Lord Masham should have done for Cartwright, in the world of art, what Lord Brougham has done for Watt in the world of literature—*i.e.*, left a lasting memorial of his great and useful services to mankind and to his country. The beautiful statue of Cartwright, which has now found a fitting place in Cartwright Hall, is shown in Fig. 3. It is admittedly worthy of him whom it commemorates, and of the beautiful memorial hall in which it is placed.

FIG. 2.—DR. CARTWRIGHT AND HIS FAMILY.

FIG. 2A.—KEY TO ABOVE:
1, Edmund; 2, Mary; 3, Elizabeth; 4, Anne Katherine; 5, Frances Dorothy; 6, Dr. Cartwright.

Dr. Cartwright had eight children, three of whom died in infancy. Those who survived are shown in the accompanying photograph (Fig. 2).

His eldest son (Edmund) became the Rev. Edmund Cartwright, Canon of Chichester, author of the "History of the Rape of Bramber" (West Sussex), 1830, editor of Mr. Dalloway's "Rape of Arundel," 1832.

For an account of his life, see the work entitled "Sussex Worthies"; also Horsefield's "History of Sussex," Vol. II, p. 145.

Mary Cartwright married Henry Eustatius Strichland. She it was who wrote the memoir of Dr. Cartwright. An account is given of the life of her son, Hugh Edwin Strichland, the naturalist, in the "Dictionary of National Biography," Vol. 55, p. 50.

Elizabeth Cartwright married the Rev. John Penrose. Under the name of Mrs. Markham, she wrote several elementary histories. There is an account of her life in the "Dictionary of National Biography," Vol. 44, p. 342, as also that of her husband.

Frances Dorothy Cartwright wrote the Life of her uncle, Major Cartwright, the Reformer, 1826. (See "Dictionary of National Biography," Vol. 9, p. 223.)

In the "Private Diary of Frances Dorothy Cartwright, being Memoranda and Reminis-

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cences begun in October, 1833," she says:— "I have some recollection of visiting Doncaster in this year (1787), and seeing my father's large mills, then newly erected. From a variety of unpleasant recollections connected with the subject of machinery, and from the dislike I felt at this time to the appalling noise and confusion of the mill, I never can see or hear machinery in rapid motion without a disagreeable sensation.

"My father, about this time, was so absorbed by his machinery that he instituted processions, etc., in honour of Bishop Blaise, the Patron of Wool-combing, which we young people disliked, as being a Popish ceremony unbecoming his clerical profession."

Many biographical dictionaries contain an account of the life of George Cartwright, elder brother of Dr. Cartwright, who was a traveller, and spent many years in Labrador; and his other brother, John (the Reformer), to whom a statue was erected (by public subscription) in St. Pancras, London, is even better known.

There is a correct biography of all three brothers in "Biographie Universelle" (Michaud), published in Paris (see Vol. 7).

In Fig. 2 is given a reproduction from a painting of Dr. Cartwright and his family. Fig. 2A is the key to this.

The Inventions of Dr. Cartwright.

The first invention of Dr. Cartwright was that of the power-loom, of which the patent is dated 1785. This idea, no doubt, originated from a conversation which took place at Matlock on the subject of the introduction of machinery.

Further patents were taken out in 1785–6–7 and 1792.

The method of working machinery then claimed his attention, and resulted in patents for the steam engine in 1797 and 1801. It is interesting to note that this latter patent was for an engine to run with ardent spirit.

The "wool-combing era" is introduced by the patent of August 22nd, 1789. This idea, however, was most crude, and the invention culminating in "Big Ben" was taken out on April 27th, 1790, followed by two other patents taken out on December 11th, 1790, and May 25th, 1792. The model of "Big Ben" was placed in the Adelaide Gallery Museum, but unfortunately all trace of this has been lost.

It is interesting to note that the seven years' patent list of this period includes inventions for weaving, combing, spinning, calendering, cutting velvet pile, and rope-making.

Other inventions followed: thus, in 1795, Dr. Cartwright took out a patent for geometric bricks.

He also patented an incombustible substitute for certain materials commonly used in constructing dwelling-houses, and invented a treadmill for working cranes.

None of these inventions appears to have been commercially successful within the time limit. Thus in 1801 he applied for an extension of his patents. From this application we learn that his comb was for long wool; that the income upon each comb amounted to £1,100 per annum, and that 50,000 wool combers were threatened by this machine. The appeal received the Royal assent on July 2nd, 1801.

He now turned his attention to a bread-kneading machine and agricultural pursuits, for which he received prizes, as intimated, from the Board of Agriculture and the Society of Arts. This period is evidently the Woburn Farm period.

Notwithstanding the extension of time granted to Dr. Cartwright for his inventions, he does not appear to have in any way repaired the financial losses which he had previously sustained. Thus a memorial was presented to the Government in 1807, and a petition from Dr. Cartwright to the House of Commons in the spring of 1808. This was based upon the power-loom — the improved quality of yarn now produced and the influence of Radcliffe's method of warp-dressing having made this an undoubted success. In 1809 Parliament granted Dr. Cartwright £10,000.

After his retirement to Hollenden he still continued his researches in chemistry, agriculture and mechanics. Thus the use of salt to prevent mildew on wheat, a method of preventing forgery on Bank of England notes, a locomotive carriage driven by human power, and finally, an engine working by explosion (gunpowder) must be ascribed to this period.

At the end of his "Memoir"—written by Mary Cartwright — is given a list of his patented inventions. This, however, is obviously incomplete, as, failing to derive any benefit from his patented inventions, he ceased to apply for patents, complaining bitterly of the inadequacy of the protection afforded.

Of Dr. Cartwright's two greatest inventions

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FIG. 3.
STATUE TO CARTWRIGHT PLACED IN THE CARTWRIGHT MEMORIAL HALL, BRADFORD.

—the power-loom and the wool-comb—the former was the first to bear fruit. He lived to see "proven to the full" the practical capabilities of the power-loom. Of the wool-comb he undoubtedly had great hopes, as instanced in the following extract from the song sung for years in the neighbourhood of Doncaster, where he established the first machine wool-combing establishment:—

SONG.—NEW BISHOP BLAIZE.*

Come, all ye master combers, and hear of new Big Ben, †
He'll comb more wool in one day than twenty of your men,
With their hand-combs and comb-pots, and such old-fashioned ways,
There'll be no more occasion for old Bishop Blaize.

What "Big Ben" was to do we have not room to record here, but in our next article we shall show how this machine became the basis of an evolution which was to effect more than Cartwright dreamed of.

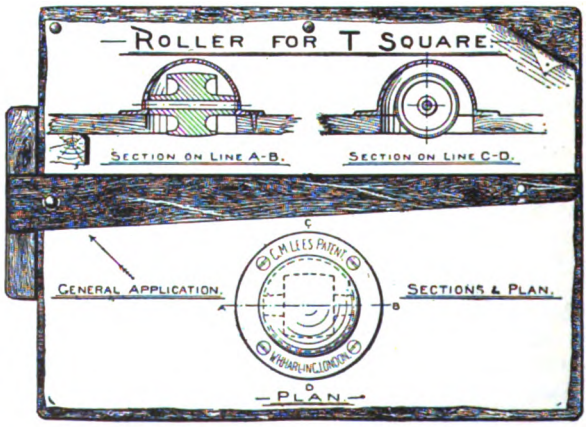
* The patron saint of wool-combers.

† The name given to the comb, from its action being similar to that of a pugilist—a man called Big Ben being a noted exponent of the art in those days.

(To be continued.)

A ROLLER ATTACHMENT FOR T SQUARES.

A USEFUL appliance to be added to the ordinary T square has recently been put on the market by Mr. W. H. Harling, 47, Finsbury Pavement, London, E.C. This consists of a small roller, in a hemispherical outer casing, fixed close up to the stock of the square; the roller projects slightly below the under surface of the blade, and bears on the drawing board or on the paper placed thereon. The outer casing, while carrying the roller, also shields it from the hand. By means of this attachment the stock is maintained in better contact with the guiding edge of the drawing board.



Friction is reduced, enabling the square to be used more rapidly, and without any of the little annoying refusals to move on the first impulse, especially in damp weather. The drawing is also maintained in a cleaner condition.

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THE GEOMETRY OF THE SCREW PROPELLER.

By WILLIAM J. GOUDIE, B.Sc., A.M.I.Mech.E.,
Lecturer on Machine Design, Paisley Technical College.

THE following notes deal with the principal features of the geometry of the screw propeller, apart from any question of design.

For an intelligent appreciation of the subject the first requisite is a clear understanding of the fundamental principles, definitions, etc., especially those connected with pitch variation; these will therefore be briefly reviewed before the geometrical and constructional portion of the work is considered.

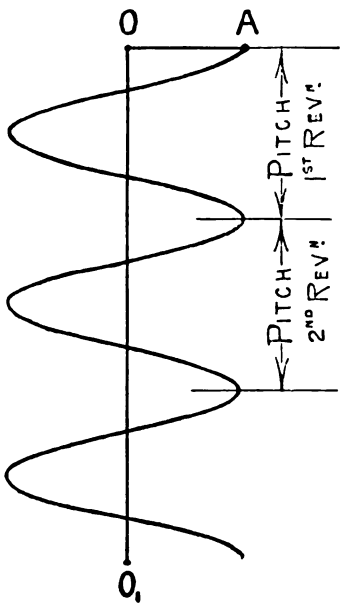

FIG. 1.–HELIX OF UNIFORM PITCH.

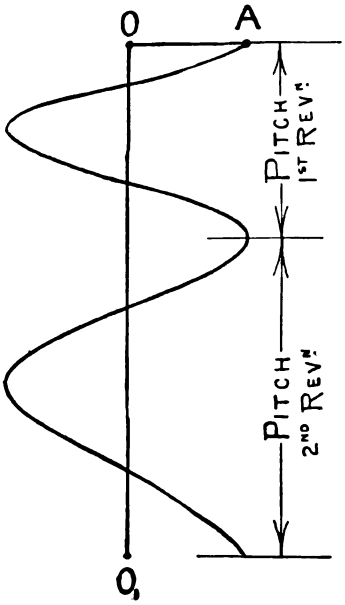

FIG. 2.–HELIX OF VARIABLE PITCH.

When a point rotates uniformly about an axis, at a fixed distance from it, and at the same time moves parallel to the axis, it describes a screw curve or *helix*, and the distance it moves parallel to the axis in one revolution is called the *pitch* of the screw.

When the point moves parallel to the axis with uniform velocity, then the axial distance it traverses is the same for each revolution, and the screw curve generated is a *helix of uniform pitch*. When the velocity is not uniform the axial displacement is different for each revolution, and the curve generated is a *helix of variable pitch*. Fig. 1 shows a helix of uniform, and Fig. 2 a helix of variable pitch, generated by the point A, which rotates uniformly about the axis OO_1 at the fixed distance OA from it.

Now suppose a rectangle OAA_1O_1, Fig. 3, is rotated uniformly about the vertical axis OO_1; then AA_1 will generate a cylinder of diameter D. If the point A is caused to travel down AA_1 with a uniform velocity while it rotates, it will describe the helix ACA_1 of uniform pitch P on the cylinder. Similarly, the line BB_1 of the rectangle OBB_1O_1 will generate a cylinder of diameter d; and if the point B is caused to travel down BB_1 with the same uniform velocity as A, it will describe the helix BC_1B_1, also of uniform pitch P on the small cylinder.

The flattened-out or developed surface of the large cylinder will take the form of the rectangle $AA_1A_2A_3$, Fig. 4, with base equal to the circumference, and height equal to P, and the helix of uniform pitch will be developed into the diagonal A_1CA_3 inclined at an angle θ to the horizontal, or plane at right angles to the axis OO_1. Similarly, the development of the small cylinder will be the rectangle $BB_1B_2B_3$, and that of the helix the diagonal $B_1C_1B_3$ inclined at a more obtuse angle θ_1 to the horizontal than A_1CA_3; and it will be evident that the nearer B is taken to the axis, the more obtuse will the angle θ_1 become. This angle, which any unrolled helix makes with the plane at right angles to the plane of its axis, is called the *angle of the screw*, and sometimes the *pitch angle*. When the helix forms part of

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the surface of a propeller-blade, this angle must not be confounded with the skew or set-back, which is the inclination aft often given to the blade as a whole; the set-back has no effect whatever on the screw angle at any part of the blade, as will be shown later.

If now a number of vertical lines touching each other be drawn on the plane of the rectangle OAA_1O_1 between B and A, these, when rotated, will sweep out a series of concentric cylinders; and if the points on them are caused to travel parallel to OO_1 with the same uniform velocity as A and B, the helices generated on their respective cylinders will all have the same pitch P. This series of helices, in contact with each other between B and A, will now constitute a helical or screw surface, of which the pitch is uniform, or equal at all points; and such a surface, when referred to in connection with a propeller-blade, is said to be a *true screw*.

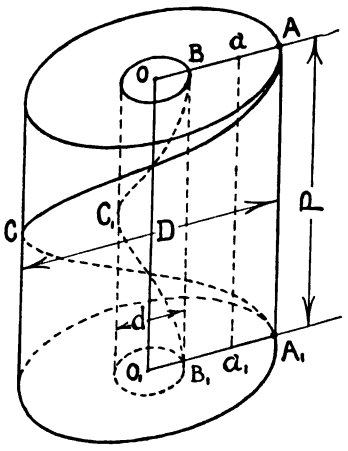

FIG. 3.—HELIX TRACED ON CYLINDER.

As the plane of the rectangle is assumed to consist of contiguous vertical lines, the points on these, at the starting position, will form the top line OA of the rectangle; and, as each point moves down at exactly the same rate, it is evident that the true screw surface can be generated by rotating the rigid line OA uniformly about the axis OO_1, while it is moved at a uniform velocity in a direction parallel to the axis. This is actually what is done in the foundry when a true screw propeller is moulded, the edge of the loam-board representing the generating line OA.

The screw surface thus formed is shown in Fig. 5, which represents a single-threaded screw of large pitch with a very deep and thin thread.

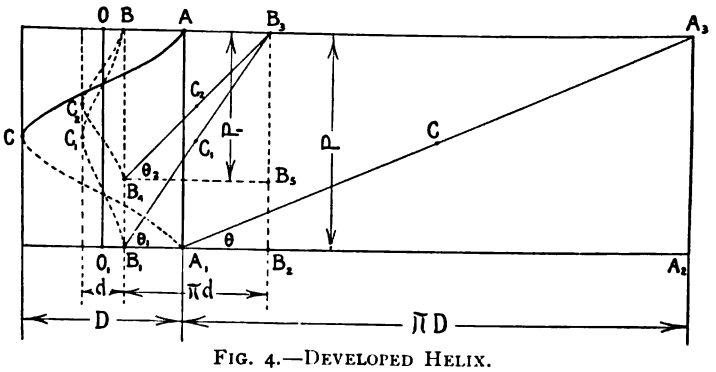

FIG. 4.—DEVELOPED HELIX.

The blade of a screw propeller constitutes only a small portion of such a thread, as indicated by the dotted outline. When there are two blades the screw is double, when three blades, treble threaded, and so on. B is a point at the *root* and A a point at the *tip* of the blade, and the distance from B to A is called the length of the blade. The length of the propeller, on the other hand, is the extreme length of blade measured in a direction parallel to the axis of the shaft.

The *boss* of the propeller, on which the blades are either cast or bolted, is represented by the short portion of the small cylinder of length L. In practice it is not made cylindrical, but spherical or barrel-shaped.

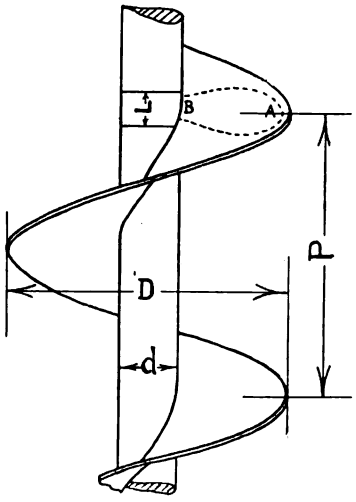

FIG. 5.—SCREW SURFACE.

Reverting again to Fig. 3, suppose that the velocities of the points A and B down AA_1 and BB_1 are still kept uniform, but that A's velocity is greater than B's.

Each, as before, will describe a helix of uniform pitch on its respective cylinder, but B in one revolution will travel a shorter distance while A travels the original one. If the rotating point next B on the second concentric cylinder is caused to move with a slightly greater velocity than B's, its uniform pitch will be greater than B's. If the point on the third cylinder moves with uniform velocity slightly

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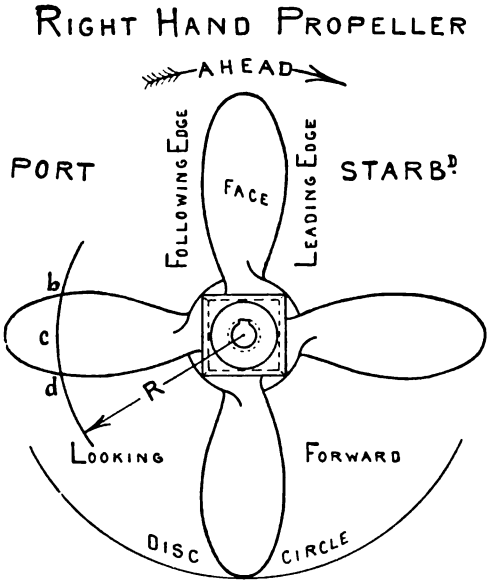

FIG. 6.

greater than that of the second point its pitch will be correspondingly greater, and so on for all the points between B and A.

It will be evident here that the helical surface, composed of the contiguous helices described by these points, is not now a true screw, as the uniform pitch of each successive helix between B and A gradually increases. A propeller blade with a surface of this type is therefore said to have a *radially varying pitch*. If for this second case the development of the small cylinder be drawn, the base of the rectangle will still be πd, but the height will be equal to P_1, and the unrolled helix $B C_2 B_4$ will be the diagonal $B_4 C_2 B_3$ inclined at an angle θ_2 to the horizontal, which will be less obtuse than the angle θ_1. The smaller pitch at the root gives a slightly broader blade there; and less churning of the water results than is the case with a perfectly true screw. The true screw blade, however, is often modified to accomplish the same object, by rounding off the edges near the root.

A propeller may be either right- or left-handed. When an observer, standing in the tunnel of a ship, and looking forward, sees the shaft rotating in a clockwise direction when the ship is going ahead, the propeller is right-handed. Conversely, when he sees the shaft rotating counter-clockwise the propeller is left-handed.

To put it another way, the blades of a right-handed propeller, when going ahead, fall from the top vertical position to the starboard, while those of a left-handed propeller fall to the port side, as indicated in Figs. 6 and 7. Both these propellers are of the four-blade built-up type, the blades being fixed to the boss by studs and nuts, which are omitted here.

The edge of each blade next the ship, which cuts down in the water when going ahead, is the forward or *leading edge;* the after one is the trailing or *following edge*. The after surface of the blade, which pushes on the water, and thus propels the ship forward, is the driving face or simply *the face*, and the surface next the ship is the back of the blade or *drag surface*.

Referring again to Fig. 3, if all the points on the concentric cylinders between B and A are caused to move with positively accelerated, instead of a uniform velocity parallel to the axis $O O_1$, then each point will describe a helix of increasing pitch, and the distance through which any point "*a*" will move during any portion of a revolution will be exactly the same as that moved through by B and A, although for each successive part of a revolution the common axial displacement of B, *a* and A will be an increasing quantity. When the face of a propeller blade is part of the surface composed of the contiguous helices thus generated, the blade is said to have an *axially varying pitch*, although "peripherally varying" seems a more appropriate term. As in the case of the true screw surface, since each point moves with the same acceleration, this surface

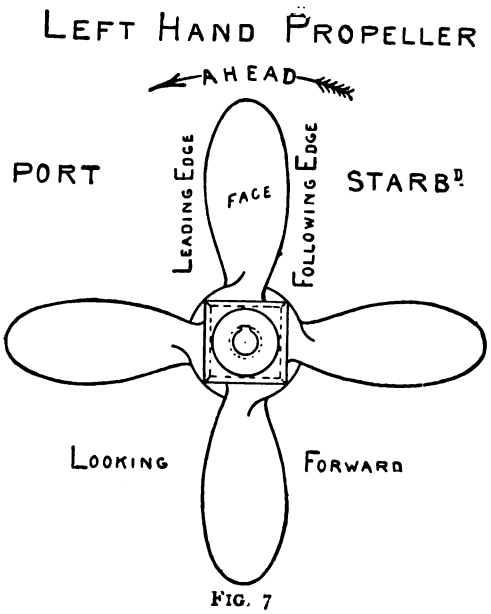

FIG. 7

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can obviously be generated by rotating the rigid line O A about $O O_1$, and at the same time moving it at a gradually increasing rate parallel to the axis.

In a case of this kind the pitch always increases from the leading to the following edge, as it is considered that a blade of this type acts on the water with less shock than a true screw one.

Although the pitch of the helix, which may be supposed to represent the intersection of the cylinder of radius Oa = R with the screw surface of the blade, Fig. 6, is assumed to be a gradually increasing one across the blade, this is not always the case in practice. The pitch at any radius is often practically constant at the lower value, from the point *b* on the leading edge to some point *c* situated about the middle of the width, where, over a small part of the width, it gradually changes to the higher value, and remains constant at this to the point *d* on the following edge.

Fig. 8 shows the development of the assumed helix of increasing pitch described by the point *a* on the cylinder of radius R. It is obtained by the usual construction, as indicated by the reference figures and dotted lines, and is a continuous curve. For the modified type of surface mentioned above, it would consist of two straight lines rounding gradually into one another at *c*. The angle of the screw at any point of the helix is obviously given by the inclination of the tangent at the corresponding point on the development curve; while the pitch is obtained by drawing a parallel to the tangent through a_1 to cut the vertical $a_2 a_3$. Thus, the parallel to the tangent at *b* cuts the vertical in a_4, and P_b is the pitch at the leading edge, while the parallel to the tangent at *d* cuts it at a_5 and P_d is the pitch at the following edge. The mean pitch is given by the parallel to the tangent at *c*.

If, now, each rotating point between B and A (Fig. 3) is caused to move parallel to the axis with a different acceleration from the one next it, the pitch of the screw surface produced will obviously not only vary axially, but also radially, and instead of the vertical $a_2 a_3$ (Fig. 8) remaining a constant height for all cylinders between the limiting radii O B and O A (Fig. 3), it will gradually increase as the radius, or, what is the same thing, as the base of the development diagram increases.

Propeller blades with this simultaneous axial and radial pitch variation are rather exceptional in ordinary practice.

The *diameter* of the propeller is the diameter of the circle described by the tips of the blades. This circle is called the *disc circle*, and its area the *disc area* of the screw.

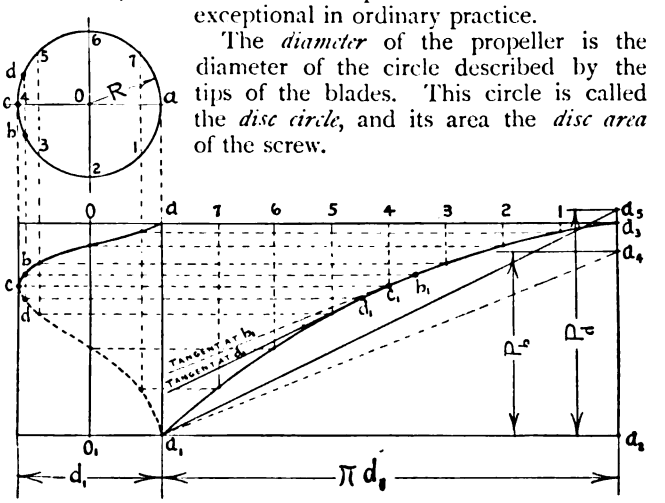

FIG. 8.—DEVELOPMENT OF HELIX OF INCREASING PITCH.

The ratio pitch ÷ diameter is called the *pitch ratio*.

The *expanded* or *developed* surface of a propeller blade is the approximate total surface of the face, which would be obtained by flattening it out into a plane surface.

The *projected* surface is the area of the projection of the face of the blade on an athwart-ship plane, or plane at right angles to the axis of the propeller; this is the effective surface for driving the ship ahead.

There are several other definitions and terms connected with the propeller, but as they have no direct bearing on the part of the subject under discussion, they need not be repeated here.

(*To be continued.*)

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SYNCHRONISING ALTERNATORS.

By FRANCIS H. DAVIES.

THE synchronising of alternators may be defined as the process of paralleling their armatures, at the instant when their momentary pressures are equal in magnitude and sign, and are increasing or decreasing at equal rates: in other words, when the voltages of the machines are equal and in the same phase.

Equality of voltage is easily determined, comparison of the voltmeters being all that is necessary. To equalise the phases, however, calls for special devices, termed *synchronisers*, the successful operation of which requires a certain amount of practical experience. For the purposes of this article, it is needless to go into the details of the various synchronisers that have been designed; those usually met with work on a principle which may be explained as follows:—

Referring to Fig. 1, Nos. 1 and 2 are two single-phase alternators. No. 1 is on load, connected to the 'bus bars B B permanently on the earthed side, and through a switch on the other side. No. 2 is supposed to be running up to speed with its main switch open, except that it touches the synchronising contact S C. The synchroniser consists of a small transformer S T, wound with two separate and equal primaries P^1 P^2, and one secondary S. P^1 is connected permanently on both sides to the 'bus bars, P^2 is connected to machine No. 2, by way of S C, permanently on one (the earthed) side, and temporarily on the other side. The secondary circuit is closed, either with a lamp, a voltmeter, or both.

Now suppose No. 2, although up to normal speed and pressure, to be in opposite phase to No. 1; that is, the negative maximum of No. 2 occurs simultaneously with the positive maximum of No. 1, and so on. The magneto-motive forces in the two primary windings being equal and opposite, produce no magnetic flux through the secondary, so that no E.M.F. is generated in the secondary: in this case the lamp will not glow, and the voltmeter needle will remain at zero. On the other hand, if the machines are in phase, the currents in the primaries, and therefore, the magneto-motive forces produced act in the same direction, with the result that the maximum flux passes through the secondary coils, and generates an E.M.F. that is clearly indicated by the voltmeter or lamp.

The approach to synchronous running is indicated by the flickering of the lamp, or the oscillations of the voltmeter needle; the slower these become, the nearer the machines are to synchronism. When the machines are very nearly synchronised, some seconds may elapse between the successive swings of the needle from zero to maximum. The reason of this may best be explained as follows:— The speeds, and therefore the periodicities, are nearly, but not quite equal; we may suppose that No. 2 is running a trifle more slowly than No. 1, so that the phases of the latter are slowly overtaking those of the former machine, coming into coincidence with them (say) every four seconds. In Fig. 2, the continuous curves represent the voltage of No. 1, and the dotted curves that of No. 2. In diagram A, the two phases are shown in direct opposition. Diagram B represents the relation between the phases after (say) one second; machine No. 2 now lags 135° behind 1. During the next second the lag is reduced to 90° (C), and in the following second to 45° (D). The fourth second brings the machines into phase. This is what happens when the deflection of the synchronising voltmeter rises from zero to maximum in four seconds.

The curves in Fig. 2 represent the pressures in the alternator armatures, but they may equally well stand for the magneto-motive

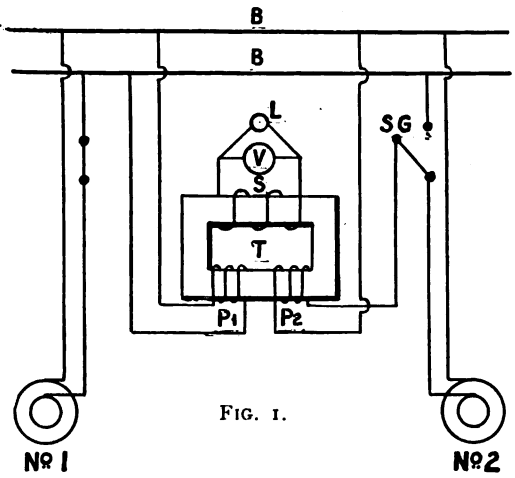

FIG. 1.

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forces in the synchronising transformer. It will be noticed that the two alternators are assumed to be equal in frequency; this is, of course, not the case, as the relative charge between the two phases is solely due to a difference in frequency. Nevertheless, in a case such as the above, where four seconds elapse between zero and maximum potential on the voltmeter, the difference in frequency is so small that for the sake of convenience it may be neglected; although it is of course necessary to understand that such a difference exists.

The magneto-motive forces in a synchronising transformer, when the two primaries are fed with currents at widely differing potentials and periodicities, may be represented by most instructive curves; indeed, this is the best means of understanding the actions that go on under such conditions. The curve of the 'bus bar voltage should be plotted, and on it should be superimposed another of different periodicity and pressure to represent the incoming machine; from this may be deduced a third or resultant curve, that will explain the action of the synchronising voltmeter under any theoretical conditions.

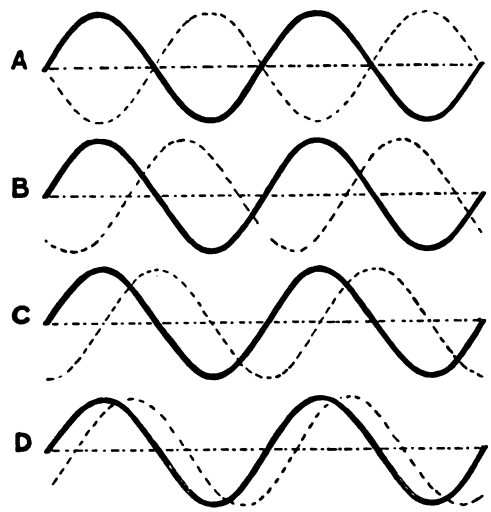

FIG. 2.

In practice, the speedy and satisfactory synchronising of alternators depends chiefly upon the skill of the man at the engine; he should have such an intimate knowledge of the particular plant, that during the operation he can keep the engine under perfect control, anticipating the exact result of every minute movement of the stop valve. The usual and best procedure is as follows:—The incoming set is started, and gradually increased in speed, the pilot synchronising lamp being watched carefully all the time. At first this will give a dull red light that flickers at a frequency so high as to be only just discernible to the eye. As the speed increases, the lamp becomes brighter, and the oscillations become slower and slower; until when the speed is practically correct, there will be a period of some seconds between the points of maximum light and darkness. Now is the critical moment of the operation. The voltmeter needle creeps slowly from zero to maximum, and just before it reaches this latter point, the switch is closed, sharply and with decision. The alternators are now in parallel.

At first sight it appears that connection should be made at the moment the voltmeter indicates maximum potential; but this is not the case, as the inertia of the moving parts (or, when a lamp is used, the time lag of the heating effect) has to be taken into account. The correct allowance to be made can be decided only from experience, as that will vary with the frequency of the alternations and the oscillation period of the needle. The lag will be the greater, the quicker the oscillation of pressure; and if, in an emergency, it becomes necessary to take what may be termed a "quick phase," as much as 5 or 10 per cent. should be allowed for—that is, providing a voltmeter of the usual "hot wire" type is in use.

It is important to remember that it is always better to close the switch too early than too late. In the first case, the machines are coming into phase, and the "motor" currents set up in their armatures, due to the premature coupling, will tend to bring the machine into synchronism. On the other hand, if the switch is not closed until the machines have started to go out of phase, even although the angular difference between the phases may be just the same as in the first case, the motor currents will be excessive, and must exert enough force to wrench the machines into their right angular relationship against their own inertia, and that of the prime mover. In the case of heavy plant this point is of great importance; and many bad breakdowns have occurred through ignorance or neglect of it.

There is yet another consideration to be taken into account in determining the correct moment to close the switch. Although the indications of the voltmeter are exactly the same, whether the incoming set is rising or falling to synchronous speed, there is a difference in results in the two cases. If the speed is rising, the inertia causes the

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machine to pick up a little load at the moment of paralleling, which acts usefully as a brake; but if it is falling, the inertia carries it still lower for an instant after paralleling, and the loaded machine is obliged to drive it as a motor to keep it in phase, unless more steam is given to the engine at once. Here again the forces act oppositely in the two cases; in the first, simply a braking effect is required, which at once produces synchronous running; but in the second, in addition to the braking effect there must be an accelerating effect, which means more power and larger motor currents.

To sum up, the ideal conditions for synchronising are, a steady and gradual increase in speed of the incoming machine, and a phase on the voltmeter taking three or four seconds to reach its maximum. Under such conditions, if the switch is closed shortly before the maximum is attained, the result should be perfect paralleling with no noise or flicker.

With almost all engines, the best way to bring the machine steadily into synchronism is by manipulating the stop valve; or in the case of large sets, by manipulating a bye-pass attached to the stop-valve. Where there is no bye-pass, and the main valve goes stiffly or has a very coarse thread, the partial opening or closing of drain cocks is sometimes resorted to in order to slightly vary the pressure in the cylinders; but this is not to be recommended, as at the best it is only a makeshift, and a poor substitute for the bye-pass.

If the engine is off the valve and under control of a governor of the variable expansion type, slight differences in speed are produced with difficulty, owing to the coarseness of the gears usually employed. In such cases it is generally preferable to synchronise on the stop valve as above, but if the governor is of the throttling type, such as is fitted to the Willans engine, very delicate adjustments of speed can be effected by its aid.

If the engine is brought in on the valve, the latter should be opened up gradually directly the switch is closed, in order to gain the steadying effect of a little load; but if it is put in on the governor with the stop-valve wide open, self-regulation occurs to a great extent.

In practice, the operation of synchronising is often much more difficult than would be anticipated. For instance, the load may be constantly varying, and with it the speed of the engines; very little alteration of speed shows markedly upon the synchroniser. Additional load suddenly thrown on may convert a phase that gave every indication of being good into one that starts to fall back just before it reaches its maximum. This occurrence must be carefully guarded against. Its prediction is purely a matter of experience; the experienced man can generally tell when a phase is going to be a short one, but it would puzzle him to say how. Such intuition, which is the essence of the art of synchronising, can only be acquired by constant practice, but its acquisition may be largely helped by a good insight into the theoretical conditions that underly the operation.

A very useful guide for indicating the condition of the incoming machine, with regard to synchronism, is the well-known optical effect produced by alternating arc lamps. Take the case of an alternator with rotating field magnets: if the light from an arc lamp is allowed to fall upon the particular alternator feeding it, the poles will appear to stand still, the reason being that the light from the arc is not continuous, but fluctuates with the same frequency as the current producing it. At the instant of maximum light, the poles are brightly illuminated, and thus rendered clearly visible.

The light now dies down, and at its next maximum the poles are seen as before, the only difference being that they have shifted forward one place, and in so doing have generated the half period that causes the momentary light in the lamp. Now if the incoming machine is at lower frequency than the one that is feeding the lamp, the poles will appear to travel backwards; instead of moving forward one place per period of light fluctuation, they advance rather less. In like manner, if the speed is higher, the poles will appear to travel forward. Instead of relying on the poles, it is usual to paint white spots on the rotating part, in number equal to the alternations per revolution.

This method, being only approximate, is useless for determining the correct moment at which to close the switch; but it serves excellently as a guide to the engine man, clearly indicating by the direction of the apparent rotation of the spots, whether the machine is running too fast or too slow.

Many alternating current systems include motor-generators in conjunction with batteries, to allow of direct current supply for electro-chemical or other purposes. In such cases the motor-generators must, of course, be synchronised. The operation is performed

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as follows:—All artificial resistance is taken out of the shunt circuit of the direct current machine, which is now run up as a motor from the battery by aid of a starting rheostat. The field of the alternator is next switched on, rough voltage adjustments made, and the synchronising apparatus put in circuit. To increase the speed of the motor-generator, resistance is thrown into the field circuit: synchronism may be thus attained if the rheostat is divided into many small sections. Very often, however, this is not possible, the speed on one stud being too low and on the next too high, in which case delicate adjustment can be made by rocking the direct current brushes either forward or backward, according to whether higher or lower revolutions are required. The field of the alternator is not excited until the machine has acquired its proper speed, since otherwise a larger starting current on the direct current side will be required, owing to the eddy currents (and consequently opposing torque) that are set up in the rotating armature.

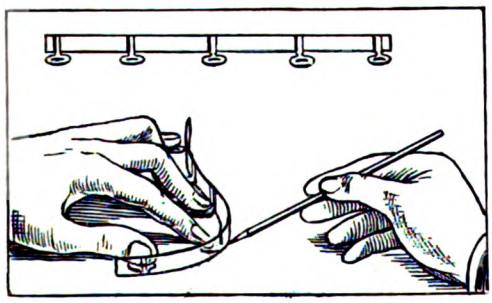
Motor-generators, being light machines, require less care than heavy plant in synchronising. Indeed, motor-generators may be thrown in when a phase difference exists that, in the case of steam sets, would result in blown fuses. Having comparatively small inertia, they are dragged into step very easily; but, for the same reasons, they do not require much in the way of a sudden increase in load to cause them to break out. The old Mordey alternator, with its immense magnets and great inertia, was one of the most difficult to synchronise well; but once in, it was indeed a severe shock that would wrench it out.

It must not be concluded from the above that careless synchronising is permissible, even with motor-generators; it sets up strains that ultimately must have a bad effect, particularly in machines like the Mordey or the Siemens, where the coils are only feebly supported. In these cases, continual bad synchronising necessitates frequent tightening up of the coils, otherwise in time a bad breakdown is sure to occur. In alternators of the ironclad type, the strains, of course, are taken up by the core, and not by the wires; but they still affect the mechanical parts of the machines, and, be it remembered, the engine through the shaft; so are always undesirable.

In this article polyphase work has not been touched upon, for the reason that the procedure is generally the same, synchronising being carried out only on one phase. Apparatus, however, is sometimes used that takes into account all the phases; but the description of such is hardly sufficiently akin to the present subject to warrant its inclusion in this article.

NOVEL DRAWING APPLIANCES.

THE plotting of observations forms an important part of any up-to-date course in physics or mechanics; hence the want has been felt of a simple appliance by means of which a smooth curve can be quickly and neatly



drawn through a number of observation points. Mr. W. J. Brooks, of 33 Fitzroy Square, W., has met this want by producing a number of flexible curves. The simplest of these consists of a strip of celluloid provided with five tabs which can be held in position by the fingers of the left hand, while the drawing pencil is held in the right hand, (see accompanying illustration). The tabs may also be held in position by means of weights or drawing pins, if required. For longer curves a strip of celluloid is provided with an arrangement which automatically clamps it in any desired shape. The value of these curves has been recognised and testified to by many eminent teachers and practical men.

Mr. Brooks also supplies a parabola carefully cut out of sheet celluloid; this should prove invaluable to students studying "conic sections," since by its aid the parabola can be quickly and accurately drawn, thus facilitating the study of the properties of the curve. In a leaflet issued with the parabola curve, instructions are given for using the latter in the graphical solution of quadratic equations.

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SPECIAL DEVICES USED IN WEAVING.

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By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

THE Art of Weaving forms the most extensive and important part of textile manufactures, whether considered on account of the commercial value, or the usefulness, variety, and beauty of its products. It also calls forth a greater number of mechanical appliances and ingenious contrivances than any other art, and is on that account alone always a source of interest to the engineer and the mechanician, as well as to the manufacturer and the weaver." Such is the eulogistic tribute to the premier branch of the textile industry paid by Mr. Alfred Barlow, in the opening prefatory remarks contained in his estimable book on "The History and Principles of Weaving," published in the year 1878.

If the weaving industry were then deserving of such eulogy, it is at least equally deserving of it at the present time. Perhaps at no other period since that worthy clergyman of the Church of England, the Rev. Dr. Cartwright, astonished his friends with his crude conception of a power-loom, has there been such active enterprise and mechanical ingenuity displayed in the interests of the textile industry generally, and of the weaving branch of that industry in particular, as is being manifested at the present time. It speaks eloquently of that reverend gentleman's clear conception of the essential functions of a weaving machine, when it is observed that, notwithstanding a lapse of nearly 120 years, with all the experience they have afforded, the essential features of his primitive loom, and the mechanical principles upon which its chief functions were based, are still embodied in the modern power-loom. Yet, what evolution has been wrought, and magnificent progress made since that wonderful germ sprang into creation; and how very crude and imperfect it would appear if placed side by side with some of its latest developments, which are veritable masterpieces of mechanical ingenuity and skill, and wonderfully complex in both their construction and operation.

Notwithstanding the high degree of perfection of modern weaving machinery, there is still much room for improvement in every department, and it is a hopeful sign that the need of such improvement was never more fully recognised than at the present time. Such is the activity of inventors and textile machinists, not only at home, but also in America and on the Continent, that it is safe to predict important changes in the textile industry in the near future. Their efforts are directed, not only towards perfecting existing types of machines and increasing their efficiency as regards both their quality of work and productiveness, but also to the invention of new systems and types of machines, with a view to increasing production and reducing the cost of same. Amongst other influences at work that may help to bring about these changes, is the introduction of automatic weft-replenishing devices in looms. This alone has created many needs and revealed many defects that were previously unknown, besides emphasising others that were formerly not so manifest. It has also led to many modifications, not only in loom construction, but in the preliminary stages of weaving as well.

Other influences of a more or less obscure character, affecting the progress and development of textile machinery generally, may be attributed to personal taste or fashion; competition between manufacturers, and between textile machinists; an increasing knowledge of electricity and its varied application to the textile industry; and, perhaps in no small measure, to technical education, now so liberally and efficiently provided in the numerous and well-equipped technical institutions, as well as by a plentiful supply of technical literature furnished in many excellent standard works and technical magazines.

The purpose of the series of articles to appear under the above title is to indicate some of the existing defects of weaving machinery, and the efforts of inventors towards effecting improvements in all departments of the weaving industry. They will also furnish descriptions of mechanical devices of a special character, and for special purposes, that may have acquired any measure of commercial success, or that appear to possess special merit. By thus embracing the whole

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range of machinery employed in, and incidental to, cloth manufacture, it is hoped that they will have a wider range of usefulness, and be of greater value and interest to a larger number of readers, than if special devices appertaining to power-looms only were selected for description.

In view of the various subjects being treated in a more or less abstract manner, and not as a progressive and continuous course of study, as in a text-book, the present writer must, perforce, presume a certain amount of technical knowledge on the part of readers. It may also be observed that, although the articles will necessarily be of a somewhat disconnected character, the subjects of which they treat will, as far as practicable, be taken in their proper departmental order—as winding, warping, sizing, beaming, and weaving.

Winding Machinery for "Twist" or Warp Yarn.

It is well known to those engaged in textile industries that yarn or thread, produced from most textile fibres of commerce, and especially that produced from cotton, wool, and silk, usually possesses elasticity in a measure which varies in different threads, chiefly according to their constituent fibres, mechanical structures, purpose, and other circumstances. This attribute not only better adapts yarn for the production of most classes of textile fabrics, but is essential in warp yarn to enable it to withstand the frequent strain imparted to it by the action of "shedding" during the operation of weaving. In consequence of its elasticity, a thread becomes thinner in proportion as it is subjected to varying degrees of tension; but if not stretched beyond certain limits it will recover its normal state on being relieved of such tension. For these reasons, it is important that elasticity and uniformity of diameter should be preserved in yarn during the preliminary stages of its manufacture into cloth. These objects may only be successfully attained by subjecting yarn to a uniform tension within certain limits as it passes through the various operations involved, and may not at first appear to present any difficulties; yet it is a problem that has greatly perplexed inventors and machine makers, who have devised numerous contrivances for the purpose of achieving those objects. The difficulties in this direction are mainly, if not wholly, encountered during the operation of winding, when yarn is transferred from any of its preliminary forms (as cops, ring bobbins, or hanks) on to warpers' bobbins, to be subsequently made into warps, or on to pirn bobbins, paper tubes, or spindles, to be used as weft. Winding machines are usually constructed on the principle of driving the spindles and bobbins at a uniform velocity. Under these conditions, and for reasons that will be presently stated, yarn is wound at a pace which is not uniform, thereby causing irregular tension upon it, and retarding production by reason of not maintaining a maximum rate of winding. These constitute the difficulties referred to.

"Cop" or "Spindle" Winding Machines.

In the type of machine known as "cop" winding machines, a number of spindles are vertically arranged in two zig-zag rows on each side of the machine. Fast upon each spindle shank is a wharved or grooved pulley, on which runs a cotton band for the purpose of driving it from a revolving tin drum, which passes centrally down the machine from end to end. The diameter of wharves on each front row of spindles is usually $1\frac{1}{4}$ in., and on each back row $1\frac{1}{2}$ in. Their velocities will, therefore, be in inverse ratio to those dimensions, or as six to five respectively. The object of driving back spindles at a slower velocity than front spindles is to enable some compensation to be made for the constantly increasing rate of winding, consequent upon the gradually increasing girth of a bobbin as additional layers of yarn are placed upon it. Thus, a winder removes half-filled bobbins from front spindles, to be filled on the slower-running back spindles; and although this affords some compensation, it is quite disproportionate to the increase in the rate of winding from the commencement, as a simple calculation will show. Fig. 1 is a graphic illustration of a warper's bobbin on which yarn has been wound in the usual barrel-form as indicated in the lower half, whilst yarn is removed from the upper half to expose the tube of the bobbin. The latter is 1 in. in diameter, and the maximum diameter of the full bobbin is 5 in. Their circumferences are, therefore, approximately 3 in. and 15 in. respectively. Therefore, assuming the velocity of front and back spindles to be 650 and 540 revolutions per minute respectively, and that a bobbin is half-filled on a front spindle, and then removed to a back spindle to be filled, the minimum and maximum rate of winding will be about 54 yards per minute at the commencement, and 225 yards per minute when a bobbin is full, which is in the

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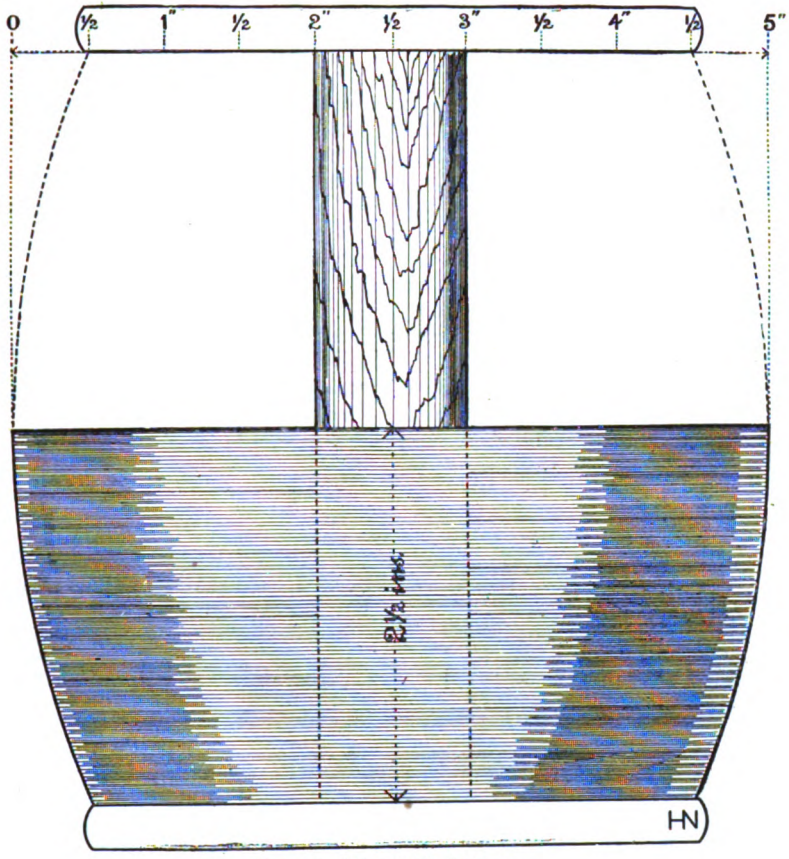

FIG. 1.—WARPER'S BOBBIN.

ratio of 6 to 25. Such an increase in the rate of winding greatly increases the frictional resistance of, and therefore tension upon, yarn, as it passes on to a bobbin. This circumstance involves a serious curtailment of production, as it prevents spindles being driven at a velocity that would maintain a safe maximum rate of winding from beginning to end; hence the velocity of spindles is such that a safe maximum rate of winding is attained only when a bobbin is quite filled.

In certain spinning machines for the production of roving or other yarn, the latter is delivered to, and wound upon bobbins, at a constant rate, notwithstanding their increasing diameter as they become filled. This is effected by means of differential driving motions for the purpose of gradually retarding the velocity of spindles to counterbalance the increasing girth of bobbins, and thereby maintain a uniform rate of winding. Such a provision is required in consequence of all bobbins in those machines receiving a constant and simultaneous supply of yarn, whereby all bobbins are built up at the same rate, and become filled at the same time. In "cop" winding machines, however, the supply of yarn to bobbins is not effected with the same precision and constancy as in the spinning machines referred to, but in a more or less independent manner, with the result that bobbins are not filled simultaneously, but at different times; hence the necessity of driving spindles at a uniform velocity throughout.

As evincing the mechanical difficulties which the solution of this problem of winding presents, "cop" winding machines of the present time are similar in their general features and operation to those constructed a great many years past; albeit their defects were known to exist more than eighty years ago, when, in April, 1822, an engineer named William Pride, of Uley, patented a device which enabled the velocity of spindles in a winding machine to be simultaneously reduced from a greater to a smaller uniform value as bobbins became about half filled. This was accomplished by employing two sizes of rope driving pulleys, of which, first

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the larger, and subsequently the smaller one, was caused to drive the tin-drum. Such an arrangement would involve both a simultaneous and continuous supply of yarn to bobbins, which, for reasons previously stated, is scarcely practicable in "cop" winding machines.

Although "cop" winding machines are universally employed for winding grey yarn (*i.e.*, of the natural colour of cotton) on to warpers' bobbins, they are entirely unsuited for winding yarn that has been previously dyed and sized. The excessive friction and chafing to which yarn is subjected, as it passes on to bobbins that are approaching completion, tends to its impoverishment, both from loss of size and richness of hue.

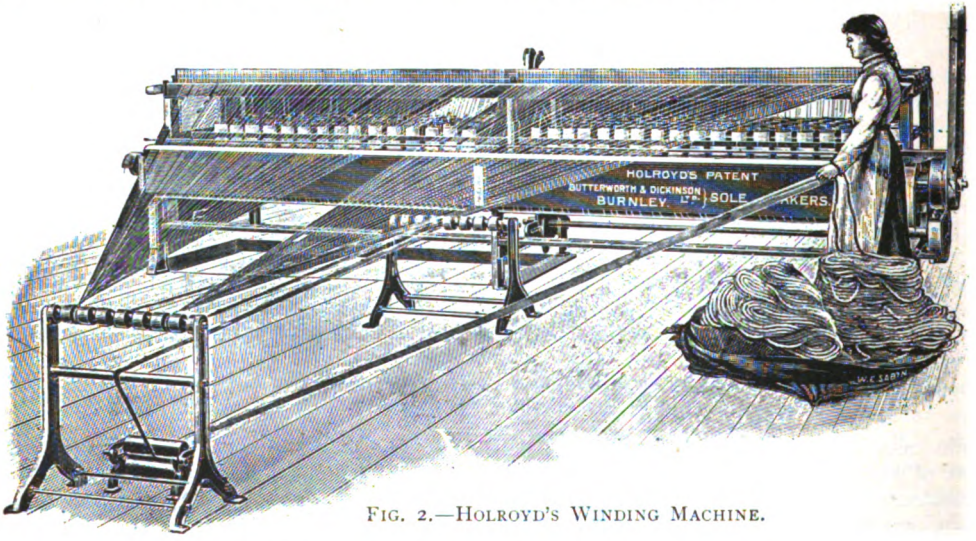

FIG. 2.—HOLROYD'S WINDING MACHINE.

For this reason, dyed and sized yarn is almost invariably wound on to warpers' bobbins by means of a "drum" winding machine, in which bobbins rest against, and are rotated by surface contact with, a series of drums fixed at intervals upon a shaft, which extends horizontally from end to end of the machine, and is driven at a uniform velocity: hence, the velocity of a bobbin is automatically retarded in proportion as its girth increases, thereby winding yarn at an approximately uniform pace throughout. Although the latter type of machine is better suited than a cop winding machine for winding dyed and sized yarn, it nevertheless possesses several disadvantages, which sometimes assume a serious character. The frictional resistance of a bobbin against the periphery of a drum during winding tends to glaze or burnish yarn, and not infrequently cause its abrasion. These evils are more pronounced in yarn dyed with colours of the more sombre hues and tones, and with the less soluble dyes that cause yarn to become harsh and rough. Also, if a hank of yarn is not free and open to permit of the easy withdrawal of its thread, it will retard the velocity of a bobbin, and thereby increase the degree of frictional resistance between it and the drum.

For the reasons stated, it is clear that neither cop winding nor drum winding machines are well adapted for winding yarn dyed and sized in the hank. It is also well known that hank dyeing yields far less satisfactory results than those obtained in warp dyeing as regards uniformity of tone.

The form in which warp yarn is dyed is chiefly determined by the system of subsequently preparing a warp for the loom. The choice usually lies between one or other of two prevailing systems, namely: (1) Yorkshire dressing, from warp-dyed yarn; and (2) sectional warping, from hank-dyed yarn; each of which has its strong advocates, according to circumstances. Without entering into the details of these systems, it will be sufficient for the purpose of this article to generally state their relative merits. Yorkshire dressing has the advantages of warp dyeing. It is invariably performed by a well-paid male operative, and the routine is generally regarded as slower and more costly than that involved by sectional warping. The latter system has the disadvantages of hank dyeing, is performed by a female operative, and is usually considered to be

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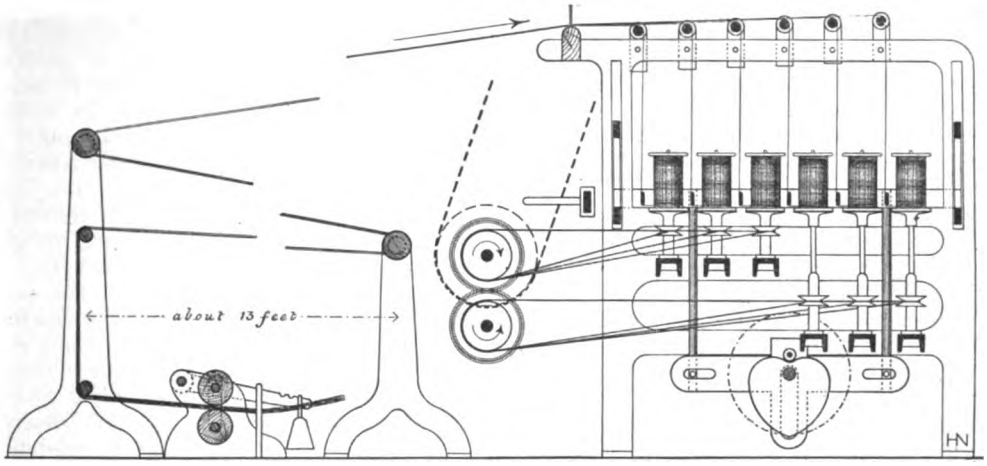

FIG. 3.—SECTIONAL ELEVATION OF HOLROYD'S WINDING MACHINE.

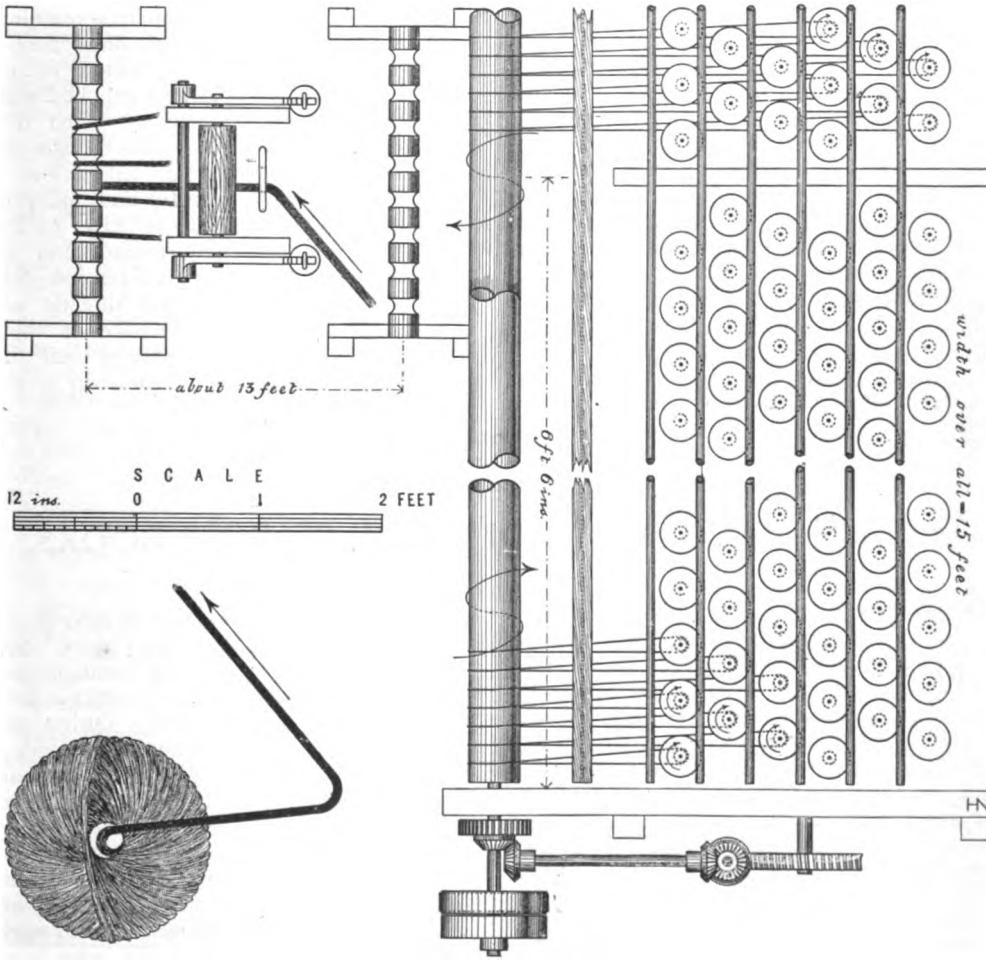

FIG. 4.—PART PLAN OF HOLROYD'S WINDING MACHINE.

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cheaper and more expeditious than Yorkshire dressing.

With the object of combining the advantages of both these systems, without their disadvantages, Mr. A. Holroyd has constructed a new type of winding machine to wind yarn from ball warps on to warpers' bobbins, from which yarn is subsequently converted into warps by means of a sectional warping machine. A perspective view showing the general appearance of such a machine is given in Fig. 2;* whilst its chief features are represented in Figs. 3 and 4, which are a sectional elevation and part plan, respectively, of the same machine. The machine contains 200 vertical Rabbeth spindles arranged in six long rows, and driven by means of cotton bands from two tin drums. In its course from the ball warp to bobbins, yarn first passes through the hand of a female attendant, who is thereby enabled to control its pace, or even stop it entirely, although the spindles may continue to revolve. After leaving the attendant's hand, yarn is subjected to tension, to facilitate the separation of threads, by passing it between a pair of weighted rollers and around tension bars. The threads are then separated by a coarse reed, which also serves to guide them horizontally to six bars, over which they bend and pass downwards to a corresponding number of vertically reciprocating guide-rails, by which they are guided on to their respective bobbins. The guide-rails are contained in a frame, to which is imparted a rising and falling uniform traverse by means of three heart-cams that work in unison. A cam is placed at each end and another in the centre of the machine to ensure a parallel motion to guide-rails; and the frame supporting the latter slides in grooves formed in each end of the machine framing, to give steadiness of action as they rise and fall.

Bobbins rest quite freely upon the metal braids or discs of the spindles by which they are frictionally rotated, as in an ordinary cop-winding machine; and spindles are driven at a uniform velocity from beginning to end of winding. This circumstance, however, does not necessarily involve a constantly accelerating pace of winding as the girth of bobbins increases. That is entirely controlled by the attendant, who may retard the supply of yarn at will, and thus compensate for such increase. If the supply is retarded, bobbins simply slip on the spindles. Such a provision is necessary by virtue of all bobbins being simultaneously supplied with yarn from a common source — when that source is a ball warp, in which threads are so liable to be of unequal tension—as it enables a bobbin to exactly and independently accommodate its velocity to the tension of its particular thread, and so neutralise any irregularity of tension that may exist. Thus, if some threads are tauter than others, the velocity of their bobbins will be slightly retarded until the slacker threads have been wound up to the same tension.

(To be continued.)

* For permission to use this illustration, the writer is gratefully indebted to Messrs. Butterworth and Dickinson, Ltd., Burnley.

THE ENGINEERING SHOP PUPIL'S NOTE BOOKS.

By R. D. SPINNEY.

THOSE students who intend to take up manufacturing branches of engineering cannot begin too early to consider engineering as a business for making money. In addition to having had good theoretical trainings, men who know best how to estimate the amount of money which must be spent (in material, wages, power, depreciation, etc.) in order to bring in certain returns, are the men who are nowadays wanted for high positions in factories.

An apprenticeship in the shops is the opportunity to learn how to buy labour, and what it costs.

The engineering apprentice so soon grows accustomed to every-day shop work that, most likely, he treats it as too commonplace to note; and he rarely realises, until too late, the great advantages he enjoys during the time he works in overalls with the mechanics. A pupil should look upon this time as some of the most privileged in his training, for it is then he has the opportunity—perhaps never to be experienced again to the same extent—for observing accurately the many causes which, taken together, control the relation of *time* to *output*.

The shop pupil should never go to work without a note-book, which he may label "Time Examples." Another note-book,

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though it need not accompany him to work, should be kept, and labelled "Time Averages."

In the first should be entered, at all opportunities, actual examples of time taken to do work. Full descriptions of turning, screwing, boring, drilling, machine tapping, milling, gear cutting, planing, shaping, punching, machine rivetting, etc.; in fact, all examples of machine work which come under observation; always giving, with each example, sizes and material of job, make of machine-tool, speeds and feeds, styles of cutting tools, and conditions as to lubrication. In conjunction with, but separate from each example, time spent in "marking off," or what supersedes this, setting up, or taking down work, grinding and regrinding tools, and other remarks (such as, if the operator is a boy or man) should be tabulated, and the date when the note is made must always accompany it.

Examples in fitting should occupy another portion of the book. Descriptions of fitting and erecting are extremely difficult to note concisely; but, with judgment, many valuable examples may be entered. Actual examples of hand-work, however, such as ratchet-drilling, tapping, studding, rivetting, scraping, etc., should be greedily collected, and full remarks as to general conditions attached to them. Notes on hand work are particularly valuable, because they are not likely to grow useless with age; thus, apart from pneumatic or electric hand drills, a man will take as long now to drill a hole by hand as his grandfather took to drill a similar hole. On the other hand, in machine work, higher powers and faster steels increase output every few years. This remark must not deter a pupil from collecting machinery data.

When a large number of actual examples have been noted the similar ones should be averaged, and reduced to simple form for entry in the "Time Averages" note-book.

For instance, under "Drilling Cast Iron" will appear approximate averages somewhat as follows:—

½-in. twist drill, 1 in. deep, time ½ minute.
1 " " 1 " " " 1 "
1½ " " 1 " " " 1½ "

Again, turning may be averaged for each diameter and per inch or foot in length, or at such a length per unit of time. Thus, under "Mild Steel Shafting: 20 feet per minute: Self-hardening cutters: Finishing cutters flat-nosed: Lubricant, suds"; a table may appear as follows:—

1¼-in.	shaft,	roughing	1	ft. in	1¾	mins.,	or 32	ft. per hr.
"	"	finishing	1	"	1	"	" 59	" "
"	"	Total	1	"	2¾	"	" 21	" "
2-in.	"	roughing	1	"	2¾	"	" 21	" "
"	"	finishing	1	"	1¾	"	" 38	" "
"	"	Total	1	"	4½	"	" 13	" "
2½-in.	"	roughing	1	"	3½	"	" 17	" "
"	"	finishing	1	"	2	"	" 30	" "
"	"	Total	1	"	5½	"	" 11	" "

and so on.

Planing may be averaged at so much time per square foot; gear-cutting at so much time per tooth of given pitch 1 inch wide. Other examples will arrange themselves according to circumstances. All such examples should be under a title of "Actual Machining, Approximate Averages"; they do not take into account time lost when the machines are not at work. This lost time will be averaged, and entered under another heading; it will vary according to class of work. To explain what is required here, the following hypothetical case may be of assistance:—

20-in. A type Cylinder, Lathe work.

Marking off and setting in lathe. . .	50 minutes.
Resetting for piston valve-seats, etc. .	25 "
Grinding, altering, fixing tools, lathe at rest	30 "
Total	1¾ hours.
Lathe running.	7 "
Grand total . . .	8¾ "

Therefore unproductive time = 20 per cent.

A number of similar castings should be treated in the same manner and their percentages averaged. A sketch showing the work will accompany the final average. Unproductive time averages should be found for as many classes of work as fall under observation, and sketches should explain each.

A book of time averages as suggested above should be carefully guarded by the student. As he advances in his profession it may become one of the most valuable of his assets.

To arrange such a book is not so difficult as may at first appear; the collecting of the necessary data will cover the whole time spent in the shops, while the averages may be worked out in odd moments.

In conclusion, let me advise students to affix source of information and data to all notes. An old note, if it does not tell from whence it was obtained, is never convincing; and if dateless, it is little better than useless.

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ARRANGEMENT OF MACHINERY IN A MODERN COTTON MILL.

PART III.—PRODUCTIONS OF FLY FRAMES (*continued*).

By WM. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

TABLE VI.—PRODUCTIONS OF FLY FRAMES.

Hank Roving.	Revolutions of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle in 10 hours.	Lbs. per Spindle in 10 hours.	Percentage of time lost in doffing, etc.
Intermediate Fly Frames.—Indian and Low American Cotton. Speed of spindle, 750 revolutions per minute. Diameter of front roller, 1⅛ in.						
0·8	198	3·78	1·07	10·968	13·71	21·0
1·0	176	4·24	1·2	10·38	10·38	16·0
1·25	158	4·74	1·34	9·75	7·80	13·0
1·5	144	5·19	1·468	9·15	6·1	10·5
1·625	139	5·40	1·528	8·89	5·47	9·3
1·75	134	5·60	1·586	8·66	4·95	8·3
Intermediate Frame.—American Cotton. Speed of spindle, 700 revolutions per minute. Diameter of front roller, 1¼ in.						
1·2	140	4·98	1·27	9·46	7·89	13·4
1·4	130	5·38	1·376	9·01	6·44	10·9
1·6	122	5·73	1·467	8·59	5·37	9·1
1·8	115	6 08	1·554	8·22	4·57	7·7
2·0	111	6·36	1·62	7·96	3·98	6·7
2·2	105	6 75	1·72	7·59	3·45	5·8
2·4	99	7·03	1·79	7·32	3·05	5·1
2·5	97	7·18	1·83	7·17	2·87	4·8
2·6	95	7 34	1·87	7·02	2·72	4·6
2·8	92	7·62	1·94	6·86	2·45	4·3
3·0	88	7·89	2·01	6·64	2·21	3·9
Intermediate Frame.—Egyptian and Sea Islands Cotton. Speed of spindle, 650 revolutions per minute. Diameter of front roller, 1⅜ in.						
1·5	157	4·12	0·954	1·11	7·41	13·8
2·0	136	4·75	1·1	0·04	5·2	9·8
2·5	122	5·31	1·232	9·67	3·87	7·2
3·0	111	5·83	1·35	9·0	3·0	5·6
3·5	103	6·26	1·45	8·47	2·42	4·5
4·0	96	6·73	1·56	7·96	1·99	3·8
4·5	91	7·14	1·65	7 57	1·68	3·2
5·0	86	7·53	1·74	7·21	1·44	2·7
5·5	82	7·90	1·83	6·88	1·25	2·4
6·0	78	8·25	1·91	6·60	1·10	2·1
6.5	75	8·59	1·99	6·35	0·978	1·8
7·0	73	8·90	2·06	6·14	0·878	1·6
Roving Frame.—Indian and Low American Cotton. Speed of spindle, 1,100 revolutions per minute. Diameter of front roller, 1⅛ in.						
1·75	155	7·06	2·0	9·29	5·31	16·0
2·00	146	7·5	2·12	8·84	4·42	13·9
2·50	131	8·3	2·37	8·25	3·3	10·4
3·00	119	9·18	2·6	7·71	2·57	8·1
3·50	111	9·9	2·8	7·24	2·07	6·5
4·00	103	10·6	3·0	6·8	1·7	5·4

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TABLE VI.—PRODUCTIONS OF FLY FRAMES (*continued*).

Hank Roving.	Revolutions of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle in 10 hours.	Lbs. per Spindle in 10 hours.	Percentage of time lost in doffing, etc.
			Roving Frame.—American Cotton.			
	Speed of spindle, 1100 revolutions per minute.		Diameter of front roller, 1¼ in.			
2·0	158	6·94	1·767	10·24	5·12	20
2·5	141	7·76	1·976	9·62	3·85	14
3·0	129	8·5	2·165	9·06	3·02	11
3·5	120	9·15	2·33	8·81	2 58	9·5
4·0	112	9·8	2·5	8·56	2·14	7·6
4·5	105	10·4	2·65	7·95	1·80	6·2
5·0	100	10·97	2·795	7·35	1·47	5·0
5·5	95	11·50	2·93	7·15	1·3	4·0
6·0	90	12·01	3·06	6·84	1·14	3·9
6·5	87	12·52	3·18	6·69	1·03	3·5
7·0	84	12·96	3·3	6·44	0·92	3·1
			Roving Frame.—Egyptian and Sea Islands Cotton.			
	Speed of spindle, 900 revolutions per minute.		Diameter of front roller, 1¼ in			
4·0	104	8·64	2·2	7·6	1·9	6·2
5·0	93	9·66	2·46	6·9	1·38	4·5
6·0	85	10 58	2·69	6·36	1·06	3·5
7·0	79	11·42	2·91	5·88	0·84	2·8
8·0	73	12·21	3·11	5·56	0·69	2·3
9·0	69	12·96	3·3	5·29	0·588	1·9
10·0	65	13·65	3·47	5·05	0·505	1·7
			Jack Frames.—Egyptian Cotton.			
	Speed of spindle, 1,120 revolutions per minute.		Diameter of front roller, 1¼ in.			
7·0	119	9·34	2·38	8·82	1·26	5·7
8·0	112	10·00	2·54	8·33	1·04	4·7
10·0	100	11·17	2·84	7·54	0·75	3·2
12·0	91	12·21	3·117	6·948	0·58	2·5
14 0	84	13·2	3·356	6·468	0·46	2·0
16·0	79	14 13	3·6	6·06	0 38	1·7
18·0	74	15·00	3·82	5·72	0·318	1·4
20·0	71	15·8	4·02	5·40	0·27	1·1
			Jack Frames.—Sea Islands Cotton.			
	Speed of spindle, 1,050 revolutions per minute.		Diameter of front roller, 1¼ in.			
16·0	70	14·92	3·8	5·364	0·335	1·9
18·0	66	15·82	4·03	5·082	0·282	1·6
20·0	62	16·68	4·248	4·83	0·24	1·3
22·0	60	17·47	4·45	4·62	0·21	1·3
24·0	58	18·26	4·65	4·416	0·184	1·1
26·0	56	19·00	4·84	4·264	0·165	0·9
28·0	54	19·71	5·02	4·088	0·146	0·8
30·0	52	20·42	5·2	3·96	0·132	0·7

An important factor in the above tables of productions is the twists per inch. Very frequently the basis of the twist is taken as the same for all the passages of Fly Frames, and one sometimes finds productions based on a common multiplier. In practice, however, it is seldom that this is the case, the factor varying with each passage and also according to the class of cotton.

The following multipliers have been used in calculating the foregoing tables:—

MULTIPLIERS FOR TWIST IN FLY FRAMES.

Indian and Low American Cotton.

Slubbers, square root of hank roving multiplied by . . . . . 1·3

Intermediates, square root of hank roving multiplied by . . . . 1·2

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Rovers, square root of hank roving multiplied by . . . . . 1·5

American and Low Egyptian Cotton.

Slubbers, square root of hank roving
Intermediates, square root of hank roving multiplied by . . . . . 1·16
Rovers, square root of hank roving multiplied by . . . . . 1·25
Jacks (American), square root of hank roving multiplied by . . . . . 1·1
Jacks (Egyptian), square root of hank roving multiplied by . . . . . 0·9

Good Egyptian and Sea Islands Cotton.

Slubbers, square root of hank roving multiplied by . . . . . 0·7
Intermediates, square root of hank roving multiplied by . . . . . 0·78
Rovers, square root of hank roving multiplied by . . . . . 1·1
Jacks (Egyptian), square root of hank roving multiplied by . . . . . 0·9
Jacks (Sea Islands), square root of hank roving multiplied by . . . 0·95

Productions of Self-Acting Mules.—Productions vary greatly in these machines, conditions not being uniform. As a basis, however, a few details are given in the following tables:—

The student must clearly understand that all the productions given are average results under certain fixed conditions. A variation from these conditions will naturally make some difference to the productions, so that if a reader is compiling a table of results he must carefully note conditions such as speeds, twists per inch, class of cotton, quality of yarn; etc.

We shall now proceed to give some practical examples of mill plans and work out the details of the arrangement of the machinery.

The first example will be the equipment of a cotton mill to contain about 80,000 spindles to spin American cotton. Average Nos. 32^s Twist and 45^s Weft.

As a preliminary the plans are given and the arrangement of machinery shown, so that the student can easily follow the method. Messrs. Dobson and Barlow were responsible for the design here shown. Fig. 4 shows the arrangement of the card room, and from it we see that the following machines are necessary:—

One bale breaker and lattice mixing arrangement; 3 horizontal exhaust openers;

TABLE VII.—PRODUCTIONS OF SELF-ACTING MULES.

Counts.	Speed of Spindle.	Hanks per Spindle in 10 hours.	Lbs. per Spindle in 10 hours.	Lbs. per Spindle per week of 56½ hours.	Hanks per Spindle per week of 56½ hours.
		Indian and American Cotton.			
16	7,690	5·84	0·354	2·06	33·0
20	8,594	5·84	0·281	1·60	33·0
30	10,272	5·75	0·191	1·08	32·5
40	10,511	5·31	0·132	0·75	30·0
50	10,350	4·87	0·097	0·55	27·5
60	9,940	4·42	0·072	0·41	25·0
		Egyptian Cotton.			
30	9,900	5·663	0·188	1·066	32·0
40	9,600	4·778	0·119	0·675	27·0
50	9,300	4·424	0·088	0·500	25·0
60	9,000	4·070	0·067	0·383	23·0
70	8,700	3·805	0·054	0·307	21·5
80	8,400	3·540	0·044	0·250	20·0
90	8,100	3·274	0·036	0·205	18·5
100	7,800	3·000	0·031	0·170	17·0
		Sea Islands.			
70	7,139	3·500	0·049	0·282	19·76
100	6,937	3·092	0·030	0·174	17·47
150	6,280	2·416	0·016	0·091	13·65
200	5,050	1·738	0·008	0·049	9·82
250	4,400	1·400	0·005	0·031	7·91
300	3·575	1·062	0·003	0·020	6·00

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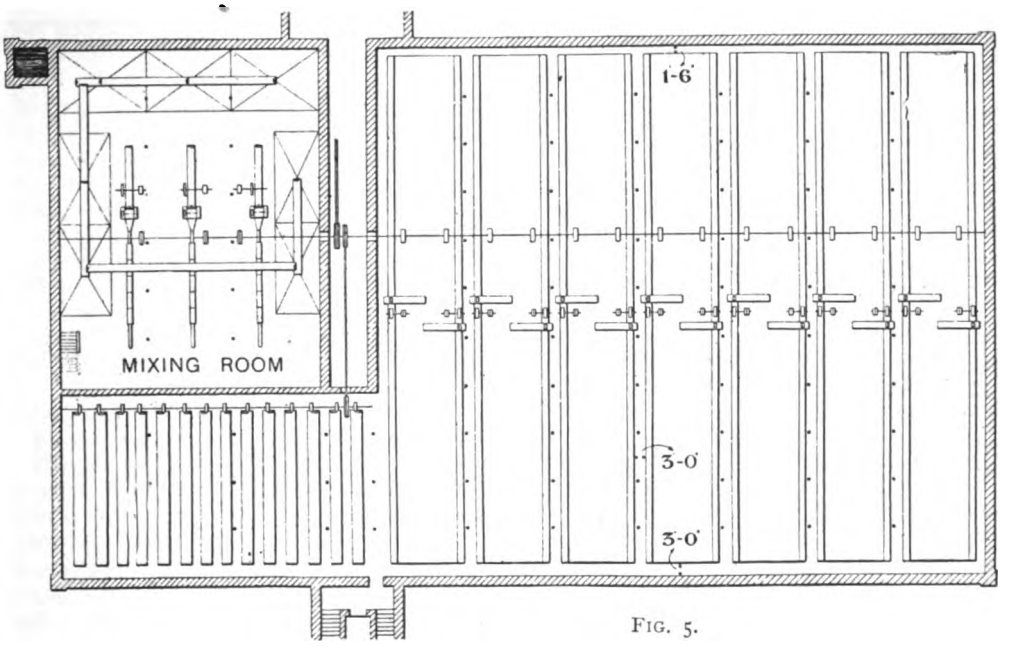

FIG. 5.

10 single scutchers; 84 carding engines; 11 draw frames, each 3 heads of 7 deliveries; 9 slubbers, each 98 spindles, 8-inch space; 16 intermediates, each 132 spindles, $6\frac{1}{2}$-inch space; 26 rovers, each 172 spindles, 5-inch space; 14 rovers in first spinning room, each 172 spindles, 5-inch space.

Fig. 5 shows the arrangement of the first spinning room, it contains 14 mules, each 1,284 spindles, $1\frac{1}{8}$-inch space; there are three more rooms above this, and each contains the following machines: second room contains 14 mules, each 1,292 spindles, $1\frac{1}{8}$-inch space; third room contains 20 mules, each 1,056 spindles, $1\frac{3}{8}$-inch space; fourth room contains 20 mules, each 1,060 spindles, $1\frac{3}{8}$-inch space.

The total number of spindles (all Mule spindles) = 78,384. A careful examination of the plans will show the most important dimensions. For instance, the inside length of mill is 228 feet and the width 130 feet 2 inches.

The arrangement of pillars has had special treatment, so that whilst in the main body of the mill we have 21 feet space, the position of the engine house has necessitated some slight differences on either side of the rope race which goes up through the mill itself. In our next article we shall show how the details given have been obtained, and explain as fully as possible the reason for the arrangement adopted.

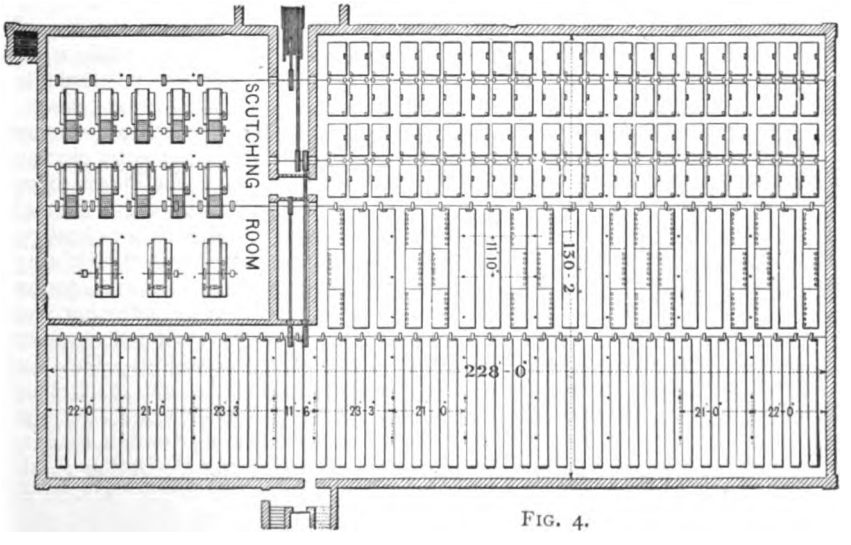

FIG. 4.

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THE FUTURE OF ELECTRIC HEATING.

By EDWIN EDSER, A.R.C.Sc.

ALL processes which depend on the production of heat at the expense of electrical energy should logically come under the title of "electric heating." One group of these processes, in which heat is produced in order to generate light, has achieved an assured success: the electric furnace, which places the high temperature of the electric arc at the disposal of the metallurgist, has found a limited but important sphere of usefulness; but the industrial use of the electric current as an agent for ordinary heating has heretofore scarcely received the attention which it deserves. Drawbacks this process unquestionably has, but these are equally apparent in connection with electric lighting: as an off-set, both processes possess certain advantages which can scarcely be obtained by other means. The chief drawback to the electrical production of heat, whether this be required for lighting or heating purposes, is the low thermal efficiency of the process. In most cases electrical energy is derived from some form of heat engine combined with a dynamo; only a small proportion of the heat supplied to the engine can be converted into mechanical energy, so that even if this could be transformed without loss into electrical energy, and the electrical energy could be wholly transformed into useful heat, the latter would still fall far short of the heat originally supplied to the engine. A Lancashire boiler can produce about 8 lbs. of steam per lb. of coal burnt, and a modern engine, without the use of superheated steam, requires about 15 lbs. of steam per brake horse-power hour;* consequently the coal consumption per brake horse-power hour amounts to about 1·9 lbs. Now a gram of average coal burnt under the best conditions can produce about 7000 gram-calories of heat; consequently the combustion of 1·9 lbs. of coal can produce $1{\cdot}9 \times 454 \times 7000 = 6{\cdot}0 \times 10^6$ gram-calories. 1 h.p. hour is equivalent to 746 watt-hours, or $746 \times 3{,}600 \times 10^7$ ergs; and this is equivalent to

$$\frac{746 \times 3600 \times 10^7}{42 \times 10^6} = 6{\cdot}39 \times 10^5 \text{ gram-calories.}$$

Consequently, under the conditions assumed, less than one-ninth of the heat derived from the coal is converted into mechanical energy, and if this energy were transformed without loss, first into electrical energy and finally into heat, we should obtain a thermal efficiency of about 10 per cent. As a consequence, it follows that light derived from the most efficient and economical electric lamp is far more expensive than that derived from gas: a given amount of light obtained by electrical means costs more than ten times as much as the same light obtained by the use of good gas mantles and burners.

Nevertheless, in spite of its greater cost, the electric light continues to hold its own, and even, so far as interior illumination of houses is concerned, to supersede gas. This points to the conclusion that the electric light possesses advantages which more than compensate its higher cost, and these advantages are not far to seek. Light cannot be obtained from gas without the production, not only of waste heat, but also of waste gases; there is also the risk of fire due to the presence of the flame—a risk which prevents the use of any sort of gas light in many situations, as for instance in workshops where inflammable or explosive vapours are likely to be present. Now the advantages possessed by the electric light are precisely those possessed by electric heating systems in general: in addition, there is less disparity between the practical thermal efficiencies of electric and other heating systems, than there is between electric lighting and gas lighting systems. The explanation of this is obvious. An incandescent gas mantle is heated in a fairly efficient manner by the flame which it envelops; but our methods of heating by the aid of fuel or steam are extremely inefficient. In the ordinary fire used for heating dwelling-houses, the coal is imperfectly burnt, with the result that the thermal efficiency of the process is low, and smoke is copiously discharged into

* The figures cited refer to recent tests of a Willans engine, with a superheat of 260° F.; only 10 lbs. of steam per B.H.P. hour were required. *See* TECHNICS, No. 9 (September, 1904), p. 214.

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the atmosphere to facilitate the formation of fogs. Further, much of the heat produced by combustion of the coal is allowed to escape up the chimney; this process, it is true, serves to ventilate the room, but an electric fan would do this better and at a smaller cost. When steam is used to heat a room, as it is in many public buildings, we still obtain a low practical efficiency. Fifteen lbs. of steam will give up* $15 \times 454 \times 537 = 3{\cdot}6 \times 10^6$ gram-calories on condensing to water at 100° C.; the same amount of steam, used in an engine, will produce 1 B.H.P. for an hour, and this energy, if converted into the electrical form by a dynamo, and finally dissipated in the form of heat by an electrical radiator, would give $6{\cdot}39 \times 10^5$ gram-calories (p. 494). But whereas electrical energy can be transmitted with extremely small loss, even to distant parts of a building or of a town, the transmission of steam to a very moderate distance may involve a loss that brings the practical efficiency of the steam heating system nearly as low as that of the electric-heating system. Further, steam radiators are somewhat unsightly in appearance, they are apt to get out of order, and the service pipes are difficult to lay without spoiling the appearance of corridors and passages. Electric radiators have great advantages in these respects; the necessary cables interfere with the appearance of a room no more than electric lighting cables. As compared with the open grate for heating dwelling rooms, the electric heater has the great advantage of cleanliness; the difficulty of solving the domestic servant problem is likely to accentuate this advantage more and more as time goes on.

An advantage of the electric system of heating is the ease and certainty with which the precise expenditure of energy needed in any circumstances can be calculated beforehand. It has been found that 120 to 150 watts are required to maintain an ordinary room of 100 cubic meters capacity at a temperature of 1° C. above its surroundings: the watts required are roughly proportional to the capacity of the room, and to the difference between the temperature to be maintained and the external temperature. During the initial heating 15 to 20 per cent. more watts should be provided for. A tram-car requires from 65 to 100 watts per passenger. All tram-cars in Switzerland are provided with electric heating apparatus, as are the officers' cabins in ships of the Italian Navy.

From the above it will be seen that, given a room or number of rooms to be heated, it is well worth while to carefully investigate the relative costs of electrical and other methods of heating, even where electricity is generated at the ultimate expense of cheap fuel. In many mountainous districts, where water-power is plentiful and fuel is dear, the electric system of heating may be found to be not only preferable on general grounds, but also cheaper than if fuel were used. Accordingly we find that hotels in Switzerland are beginning to adopt the electric system; an hotel at Moserboden, accommodating 120 people, has recently been installed with a complete electric heating system, by which the rooms are kept at a uniform temperature, hot water is provided for the baths and laundry, and heat is supplied to the cooking utensils, including a baker's oven. Electric cooking utensils compare very favourably with the ordinary fire-heated appliances, both in thermal efficiency and in cleanliness and effectiveness. In cooking by means of a fire, only a small fraction of the heat produced during the operation is usefully employed; further, much heat is lost during the preliminary preparation of the fire, and after the cooking has been completed. In the electrical apparatus, heat is produced just where and when it is wanted, and is perfectly under control; in electrical saucepans and frying pans, the heat is produced in the base of the utensil, which can be stood on a table while the cooking progresses. The electrical supply companies charge for electrical energy used for cooking at the "power" rate, *i.e.*, 2½d. per unit, instead of 6d. per unit charged for lighting purposes. Many companies have expressed their willingness to make further reductions, with the object of obtaining a reasonable day load. Consequently a chop can be cooked on an electric grill for less than 0·1d., while a chicken can be cooked for about 0·3d.

It is in manufacturing operations, however, that the most important applications of electric heating are likely to be made; indeed, certain processes have already been simplified and rendered more efficient by the utilisation of the electric current as a heating agent. For instance, the soldering up of tins containing benzoline and other inflammable liquids had to be performed in the open air, so long as flame-heated soldering bits were alone available; but the advent of the electric soldering bit has made it possible for

* Very little advantage is gained by using superheated steam for heating radiators, etc. *See* "Heating and Ventilation," by W. W. F. Pullen, TECHNICS, No. 2 (February, 1904), p. 109.

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FIG. 1.—ELECTRICALLY-HEATED SOLDERING BIT.

such operations to be carried out with perfect safety under cover. The drying of explosives, and certain heating operations in connection with the manufacture of celluloid, also come under this head. There are many industrial operations which require the application of heat for fairly long periods, subject to the condition that the supply must be perfectly under control; the manufacture of ebonite, and the vulcanisation of rubber goods (including waterproofed fabrics), suggest themselves in this connection. In such cases the cost of the heat supplied is only an insignificant fraction of the total cost of the process, so that, even if electric heating were much dearer than it is, it would probably be adopted with considerable benefit. In countries where water-power is plentiful and fuel is dear, the economy of certain manufactures has been so much enhanced by the use of electric heating that profitable production has been rendered possible under conditions that otherwise would be inimical to success. In the near future electric heating will almost certainly be used to a large extent in the manufacture of wood pulp in countries like Norway and Sweden.

FIG. 2.—RADIOGRAPH OF ELECTRICALLY-HEATED FLAT IRON.

Considering the many advantages inherent in electric heating, it may appear surprising that it has not been more extensively adopted up to the present time. Attempts to utilise these advantages have, indeed, been made in the past, but their failure was due to the flimsy construction of the apparatus employed. Metal wires separated by strips of mica, and other similar devices, proved to be too untrustworthy for industrial use; accordingly, no progress was made until electrical heating apparatus was constructed on an engineering scale. At the present time most of the difficulties which baffled the earlier experimenters have been successfully overcome. One of the most successful methods now employed is to enclose a spiral of wire, to be heated by the electric current, within a solid mass of baked clay. The construction of the electrically heated flat-iron may be taken as typical of modern practice. The heating spirals are made of "constantan"—an alloy of nickel and iron* which possesses an exceptionally high resistivity, combined with a small temperature coefficient, and can be produced at a moderate cost. A clay possessing the required properties was only found after prolonged research; this clay is formed into a slab of the requisite shape, grooves to contain the heating wires are pressed into its upper surface by means of a die, and after the wires have been placed in position, another similar slab of clay is laid upon it. If required, this process may be repeated, so that a number of heating spirals are arranged in parallel planes, one above the other. The clay is next carefully dried and then baked;

* For the electrical properties of nickel-iron alloys, see a paper on "The Electric and Magnetic Properties of Alloys of Iron," by W. F. Barrett, F.R.S., and W. Brown, B.Sc.; TECHNICS, No. 2 (Feb. 1904), pp. 123–125.

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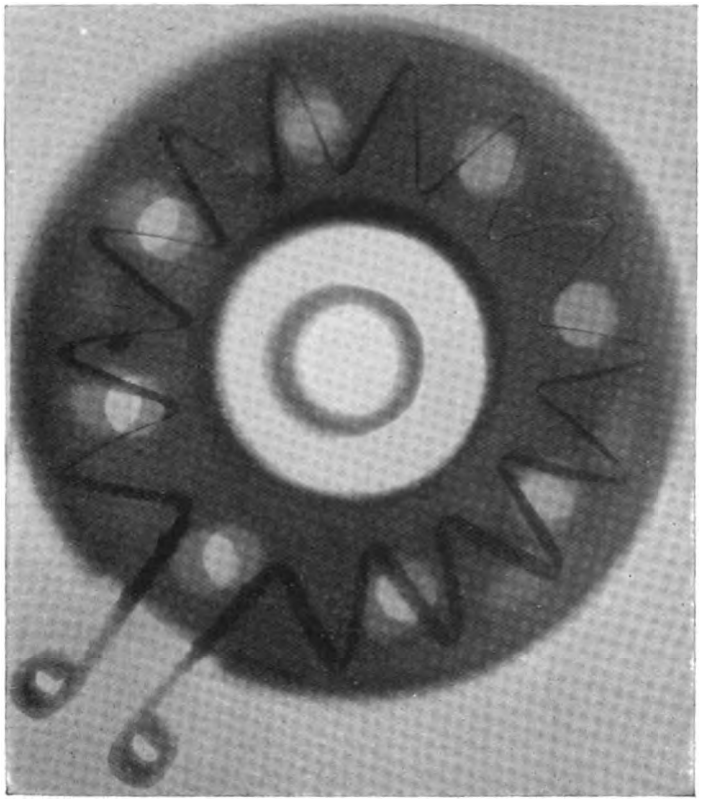

FIG. 3.—RADIOGRAPH OF ELECTRIC HEATING ELEMENT.

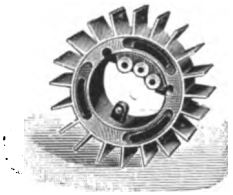

FIG. 4.—ELEMENT OF ELECTRIC RADIATOR.

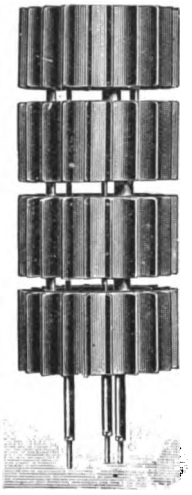

FIG. 5.—BATTERY OF ELEMENTS SIMILAR TO THAT REPRESENTED IN FIG. 4.

finally, it is used as a core round which a metal shell is cast. The contraction of the metal during solidification and cooling causes it to firmly grip the clay core, so that the whole becomes as rigid and strong as a solid block of metal. Fig. 2, for the use of which I am indebted to Mr. Isenthal, is reproduced from a radiograph of the core of a flat-iron; the wires, being more opaque to the X rays than the baked clay, cast shadows on the plate, and the positive shows them as dark lines on a lighter ground. Fig. 3 is reproduced from the radiograph of one of the units similar to those used in building up a "radiator"; in this case a *strip* of constantan is used instead of wire, and is embedded in the walls of a hollow cylinder of baked clay. One of the radiator elements is shown in Fig. 4; the metal case provided with ribs or fins is made from aluminium. In Fig. 5 a number of these elements are shown connected together. In soldering irons (Fig. 1), the clay containing the embedded heating wires is enclosed in a conical brass case, cast *in situ* as before described. For heating large volumes of water, the wires are contained in metal tubes, from which they are insulated by clay beads.

Taking everything into consideration, it appears that electric heating is likely to be extensively employed in the future, not only for domestic purposes, but also in the arts and manufactures; its use is extending day by day, and in cases where it has once been adopted its use has been continued. The disadvantages under which it labours are present in a still greater degree in the use of electricity for lighting; and unless we are prepared to prophesy the ultimate supersession of the electric by the gas light, it is only reasonable to suppose that the inherent advantages in the use of electricity as a heating agent, which are common to electric heating and electric lighting, will lead to an ever-widening field of usefulness for both processes.

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THEORY OF STRUCTURAL DESIGN.

PART XI.—STEEL PILLAR DESIGN.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

IN the October number of TECHNICS, a series of working loads for pillars were obtained by combining Gordon's formula for the breaking load with Shaler-Smith's rule for the factor of safety.

We can obtain a similar diagram of working loads if we combine Claxton Fidler's or Rankine's equations for the crippling loads with the factor of safety formulæ given in the previous issue of this magazine.

The time saved by such a method is very marked, for we should otherwise require to calculate the working load for each particular case, although the crippling load may be already tabulated.

The crippling load in tons per square inch for built-up mild steel pillars with flat ends has previously been given as $\frac{18}{1 + \frac{1}{18000}\left(\frac{l}{r}\right)^2}$

where l = the length of the pillar in inches, and r = the least radius of equivalence (or gyration) in inches.

The factor of safety F for quiescent loads

$$= 4 + \frac{K}{100}, \text{ where } K = \frac{l}{r}.$$

TABLE GIVING CRIPPLING LOADS AND SAFE LOADS FOR PILLARS.

Length divided by least radius of equivalence.	Crippling load in tons per square inch.	Factor of safety for steady loads.	Safe load in tons per square inch.
$\frac{l}{r} = K$	$\frac{18}{1 + \frac{K^2}{18000}}$	$4 + \frac{K}{100}$	For flat ends and steady loads.
20	17·6	4·2	4·2
30	17·0	4·3	4·0
40	16·5	4·4	3·75
50	15·8	4·5	3·50
60	15·0	4·6	3·25
70	14·2	4·7	3·0
80	13·2	4·8	2·75
90	12·2	4·9	2·5
100	11·5	5·0	2·3
110	10·8	5·1	2·1
120	10·0	5·2	1·93
130	9·3	5·3	1·76
140	8·6	5·4	1·6
150	8·0	5·5	1·45
160	7·5	5·6	1·34
170	6·9	5·7	1·20
180	6·5	5 8	1·12

The working load in tons per square inch equals the crippling load in tons per square inch divided by the factor of safety.

Fig. 45 and the accompanying table give the working loads for different values of $\frac{l}{r}$ as obtained from the above equations.

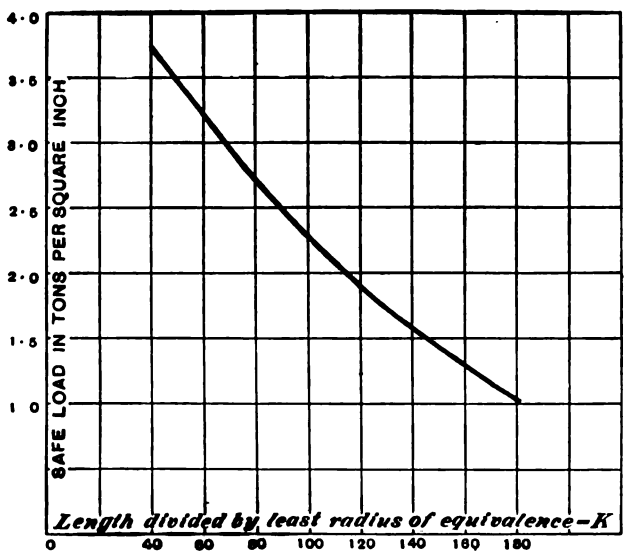

FIG. 45.—CURVE SHOWING SAFE LOADS FOR PILLARS.

Fig. 45 very clearly shows that the wider a pillar is in relation to its length, the greater is the permissible load per square inch, and therefore the less material will be required. The pillar formula is not necessary for values of $\frac{l}{r}$ less than about 40 if the ends are firmly fixed. Pillars having a value of $\frac{l}{r}$ greater than about 140 are very extravagant, as they require so much metal to carry a small load.

It should be borne in mind that the crippling load per square inch is a quantity quite different from the crippling stress per

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square inch; and the safe load per square inch is not the same as the safe stress per square inch.

For instance, the unavoidable eccentricity of loading and want of initial straightness, etc., may cause a long slender pillar to buckle and collapse on account of the internal stresses exceeding the elastic limit, although the external end load may have an intensity of less than one ton per square inch of pillar section. In crude syllogistic form we may say:—

1. The crippling load per square inch in long pillars depends upon the ratio $\frac{l}{r}$, and is a variable.

2. The crippling stress in long pillars does not depend upon $\frac{l}{r}$, and is a *constant.*

(3) Therefore the crippling load per square inch is not identical with the crippling stress. The crippling stress, in fact, denotes a property of the *material,* while the crippling load denotes a property of the *pillar.*

In a tie rod, where there is no tendency to buckle, the extraneous load per square inch is numerically equal to the internal tensile stress per square inch; but in pillars we have the effect of the inevitable lateral deflection and bending stress to consider. I have, perhaps, laboured this point; but it is because I am convinced that the confusion of these two ideas lies at the root of many misconceptions as to the precise meaning of even the simplest pillar formulæ.

The student will also do well to pay attention to the following points. The plane of bending (the deflection plane of a pillar) is that vertical plane in which bending is most apt to take place. In the case of central or axial loads, the plane of bending lies in the direction of the least radius of equivalence.

In the case of one-storey pillars, the length to be used in the formulæ here given is the over-all length, including cap plate and base plate, and not the length of the parallel shaft or trunk which is clear of gusseting. In the case of two or more storied stanchions, which are rigidly fixed at the different floor levels in two directions at right angles to each other, the different floor levels may be looked upon as dividing this continuous stanchion into a series of shorter ones. If a stanchion several stories in height is fixed at each storey by two beams at an angle of 180°, no advantage will accrue from such fixing unless the insertion of the beams will place the plane of bending at a horizontal angle of 90° from its former position.

In such cases it is requisite in calculations to use the height of one storey for the bending in one plane, and to use the full height of the continuous stanchion for the bending in a plane at right angles to the former position. The student will do well to bear in mind that the least radius of equivalence (or gyration) is always in a direction at right angles to the maximum radius; and that the radius for any intermediate position of the neutral axis can be obtained by drawing an ellipse passing through the minimum and maximum radii.

Referring to Fig. 46, let O be the centroid of any cross section, and let X X represent the neutral axis. The neutral axis is, of course, at right angles to the plane of bending, and the plane of bending is pre-determined by the relative position of the cross-section and the load.

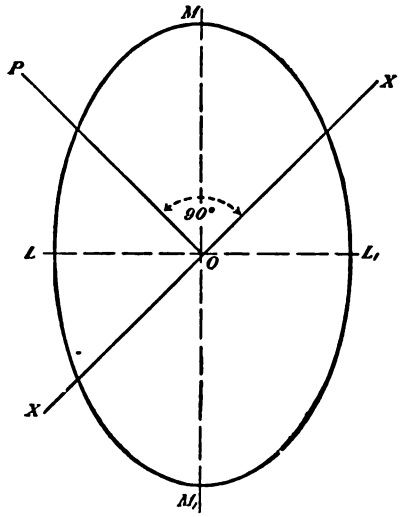

FIG. 46.—GRAPHICAL METHOD OF OBTAINING THE RADIUS OF EQUIVALENCE IN ANY GIVEN DIRECTION.

Let M O represent the maximum radius of equivalence, and let L O represent the least radius. The curve M L M_1 L_1 is an ellipse. The radius of equivalence for any given position of the neutral axis, such as X X, is given by the intersection of O P with L M. This curve is sometimes called the ellipse of inertia. If there is very little difference between the maximum and minimum radii, the ellipse will tend to become circular; when the radius of equivalence is the same, no matter what the direction of the neutral axis is, the ellipse becomes truly circular. These rules are very useful for finding the

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radii of equivalence of such sections as that illustrated in Fig. 43 of the October issue.

If steel stanchions are embedded in massive walls, it is quite permissible to take the radius of equivalence in a horizontal direction at right angles to the face of the wall; but if stanchions are placed between brick or terra-cotta panels, or thin partitions, no such modification should be made: no allowance should be made for the lateral stiffness afforded by even thick walls, if the walls are much broken up by window openings.

If a pillar be not strong enough for its purpose, it is not necessary to go over all the calculations again to discover the radius of equivalence for the amended section, so long as the requisite area be supplied by plates placed so as to increase the diameter of the stanchion in the direction of bending. Under these conditions, we are always on the safe side if we consider the radius of equivalence to remain the same, although it will really be increased, but perhaps only by a very small amount. This approximation is very useful, because otherwise we shall perhaps have to spend half an hour of tedious calculation in trying to adjust the radius of equivalence, the cross-sectional area and the maximum safe intensity of the load, for we find, as soon as we have got one of these quantities right, that we have disturbed the other two.

Pillar Bases and Caps.

Pillar bases and caps are sometimes divided into two classes—fixed ends, and free or rounded ends.

This seems very plausible on paper, but the distinction is too sharply drawn to be entirely true in practice. Absolutely fixed ends and absolutely free ends are extreme cases, and probably 90 per cent. of actual pillars are neither truly fixed nor yet really free in the mathematical sense in which those terms are used. The usual built-up steel stanchions, with mild steel bases and cap plates with gussets at top and bottom, fall between these extremes, and tend to the fixed or the free condition, according to the skill of the designer and the quality of the workmanship, etc.

It is not so much the external form or appearance of the pillar ends which determines their fixity or freedom, but the degree of mechanical perfection or imperfection which exists. In the mathematical sense, a loaded pillar is deemed to have fixed ends, if the axis of the pillar at its extremities be forcibly maintained in an absolutely vertical direction. Such a pillar is unable to deflect laterally without producing two or more points of contraflexure. A pillar is deemed to have free ends if it is free to act as though it were placed between knife edges top and bottom, or as though it had frictionless hinges at each end, and were free to take up the form shown in Fig. 47.

These are clearly extreme hypothetical cases. A roof strut, with one rivet at each end, is assumed to have free ends; but as a matter of fact, there may be considerable friction between the rivetted surfaces. It would, of course, be very dangerous to trust to such uncertain fixity, but we cannot deny its existence. On the other hand, it is very usual to consider flat ends as fixed ends; but suppose the holding-down bolts are not tight, what is to prevent a free rocking of the pillar if the top of the concrete foundation block be slightly convex?

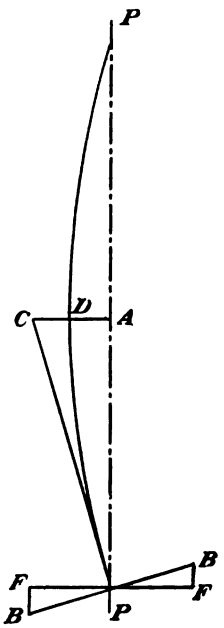

FIG. 47.

It is instructive to note how little movement is required at a pillar base to produce appreciable curvature in a pillar. Take, for example, the pillar shown by skeleton lines in Fig. 47.

Let P P represent the perpendicular line joining the two extremities of the pillar. Let P D P be the centre line in the deflected position. If P D P be a parabolic curve, the geometrical tangent at P is given by the line C P, which is obtained by making C A twice as long as D A. C P, then, will give us the direction of the axis of the deflected pillar at the base. Let B B represent the width of the base of the pillar. C P B is a right angle, and A P F is a right angle, therefore the angle C P A is equal to the angle B P F. C A P and B P F are similar triangles. Therefore

$$\frac{BF}{PF} = \frac{CA}{AP}$$

Let B F = $\frac{1}{10}$ in., *i.e.*, suppose the edge of the pillar base to be canted 0·1 in. higher than P. Let P F = 12 inches.

Let A P = 20 feet = 240 inches. Then

$$\frac{0{\cdot}1 \text{ in.}}{12 \text{ in.}} = \frac{CA}{240 \text{ in.}};$$

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$$\therefore \frac{240 \text{ in.} \times 0{\cdot}1 \text{ in.}}{12 \text{ in.}} = CA = 2 \text{ in.}$$

The deflection of the pillar $= \frac{CA}{2} = 1$ in.

We see, therefore, that a movement of one-tenth of an inch at the edge of a base plate may be accompanied by a lateral deflection of one inch in the middle of the stanchion. If the accidental eccentricity of the axis of the stanchion at the middle was formerly half an inch, an added deflection of one inch would treble the stresses due to bending.

The working loads here tabulated are low enough to allow for these contingencies, and should ensure good construction. The rule for the factor of safety here given was designed for steady loads on all classes of mild steel pillars, and not specially for the crippling load formula with which it has herein been coupled.

(To be continued.)

ELECTRIC SELF-WINDING CLOCK.

A NOVEL departure in horology is marked by the invention of a clock which is automatically re-wound at short intervals by electrical means. The contraction of a spring actuates the mechanism of the clock, but at the end of every six or seven minutes the spring is extended by the aid of an electro-magnetic device, so that the clock continues working for years without attention.

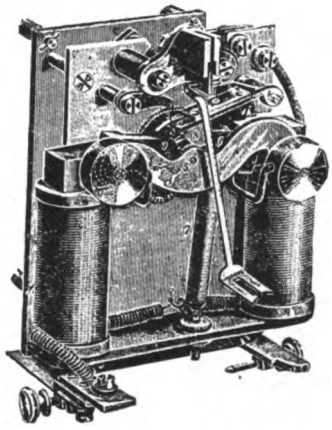

FIG. 1.—ELECTRIC SELF-WINDING CLOCK.

The arrangement adopted by the Self-winding Clock Syndicate is shown in Fig. 1. The contraction of the spring 7 actuates the mechanism of the clock; at the same time it rotates a soft iron armature about the axis 5. For the greater part of the time the electro-magnet is unexcited; but when the inclination of the armature reaches a certain value an electric contact is made which excites the magnet, and so pulls the armature into a horizontal position, thus producing a small extension of the spring 7. The electrical contact is then broken, the magnet ceases to be excited, and the contraction of the spring works the clock until another contact is made, when the above process is repeated.

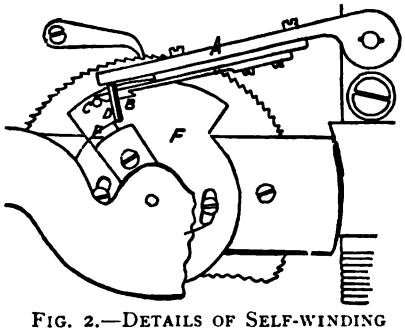

FIG. 2.—DETAILS OF SELF-WINDING CLOCK.

Fig. 2 will explain how the operations described above are effected. Attached to the armature is a plate F, which carries the electrical contact E. A swinging arm A carries a pin D, which, when it touches E, completes the circuit of the electro-magnet. Attached to the lower surface of A is an insulated metal spring provided at its free end with a head B, which rests on a pin C, carried by the plate F. For the greater part of the time the head B of the spring is held up by the pin C, with the result that the arm A is raised, and D does not make contact with E; but when the armature reaches its maximum inclination, the pin C slips past the right-hand end of the head B, so that B sinks and the pin D makes contact with E; the magnet is then excited and twists the armature into a horizontal position, and subsequently the pin C raises B and with it the arm A, thus breaking the electrical contact.

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REVIEWS.

The Metallurgy of Steel. By F. W. Harbord, A.R.S.M., F.I.C., Consulting Metallurgist and Analytical Chemist to the Indian Government. With a section on **The Mechanical Treatment of Steel. By J. W. Hall, A.M.I.C.E.** pp. xxiv. + 758, with 37 folding plates, over 280 illustrations in the text, and nearly 100 photo-micrographs of steel sections. (London: Charles Griffin & Co., Ltd., 1904.) Price 25*s*.

There is no manufacture which is of so much importance, either to a particular country or to the world at large, as that of steel. In the past the production of steel in quantity was to a great extent confined to England, but latterly the greatest developments in the steel industry have occurred in the United States. The development of the continent of America has created an unprecedented demand for steel, and has given the American steel manufacturer an opportunity to utilise the latest scientific knowledge at his disposal, and also to organise research for further knowledge. At the present time Messrs. Harbord and Hall's book should do much to promote progress in steel manufacture in England, since it contains an able and exhaustive account of the progress made up to the present time; no pains have been spared to make the book both trustworthy and well up to date. The book is divided into four sections: the first, on the Manufacture of Steel, is by F. W. Harbord; the second, on Reheating, is by F. W. Harbord and J. W. Hall; the third, on the Mechanical Treatment of Steel, is by J. W. Hall; the fourth, on Finished Steel, is by F. W. Harbord. The whole is written so as to be of use to the student, the works manager, the engineer, and the chemist. In the first section, special attention has been devoted to methods of steel manufacture used in the United States and on the Continent. The latest types of steel furnaces, gas producers, mechanical appliances, as well as Bessemer and open-hearth furnaces, are described and illustrated by scale drawings. The treatment of the ingot after leaving the casting pit is described in the second and third sections. The reheating of steel is a subject demanding not only metallurgical, but also mechanical knowledge of the highest description. As it would be almost impossible for a single person to possess the requisite knowledge and experience, Mr. Harbord wisely collaborated with Mr. J. W. Hall in producing this section, which includes a description of the latest coal and gas fired reheating furnaces, mechanical chargers, and the various appliances required for handling the materials at the furnace and conveying them to the mills. The third section has been written entirely by Mr. J. W. Hall. It includes a description of the latest improvements in mills for rolling plates, bars, billets, and rods; labour-saving appliances also come in for a due share of notice. The chapter on the arrangement and disposition of the stock yard should prove of great use. The fourth section, dealing with the properties of Finished Steel, should be read not only by those directly interested in steel manufacture, but by all engineers: the experimental physicist would also find much information of the greatest value to him in his researches. The modern subject of Heat Treatment is fully discussed; the latest forms of pyrometers are described. The microstructure of steel is dealt with in a masterly manner; the photo-micrographs used to illustrate this part of the book are particularly well reproduced. Various theories, such as M. Osmond's theory of allotropic steel, Professor Arnold's carbon and sub-carbide theory, the solution theory, etc., are described and discussed. In the appendix, the subject of specifications is dealt with; a number of specifications by leading engineers in England and America are given for comparison. One or two errors may be noted. Aluminium added to steel does not, as stated on p. 213, increase its fluidity. Further, we are told, on p. 213, that to obtain good castings "it is better to keep the temperature too low rather than too high;" while on p. 218 we read that "as smoother castings are obtained from hot metal, it is better in many cases, where this is of special importance, to cast hot." The latter statement is quite inconsistent with the best foundry practice.

The above, however, are but minor blemishes. Taken altogether, the book should prove of the greatest service to all those interested in the manufacture and properties of steel; and the authors are to be congratulated on the successful completion of a task which must have involved no small amount of labour.

The Electric Furnace. By Henri Moissan. Translated by **A. T. de Mouilpied.** pp. xii. + 307, with forty-one illustrations. (London: Edward Arnold, 1904.) Price 10*s*. 6*d*. net.

Although the electric furnace has been with us only for about twelve years, it has attained such an assured position that one is apt to forget the importance attaching to its introduction. In 1892, acetylene was an uncommon

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gas which could only be obtained pure with difficulty. Crystallised calcium carbide was unknown, as were the richer alloys of chromium, manganese, vanadium, titanium and iron. Finally, a large number of refractory metals, including chromium and manganese, were museum curiosities, while their properties in the pure state were unknown. The scientific advances due to the use of the electric furnace are in great measure due to the work of Moissan, so that a book on that subject by this distinguished author, ably rendered into English, will be sure to meet with a cordial reception. By the aid of the electric furnace, temperatures of 3,500° to 4,000° C. can be obtained; at these high temperatures all known elements and compounds may be vaporised. Further, at these high temperatures compounds can be formed which cannot be produced otherwise. While Moissan has pushed his researches into regions of high temperature, Dewar, Olzweski, Ramsay, and others have investigated the chemical and physical properties of substances at low temperatures; so that at present the field of research open to the investigator ranges from —257° C. to about 4,000° C. The first chapter of M. Moissan's book contains a description of the different types of electric furnace, the crystallisation of metallic oxides, and the fusion and volatilisation of refractory substances. The second chapter is devoted to researches on the different varieties of carbon, including amorphous carbon, graphite, and the artificial production of the diamond. It appears that the diamond is formed when carbon crystallises out from a solution under high pressure. Moissan was almost certainly the first investigator to produce diamonds artificially; others before him had produced crystals resembling diamonds to a greater or less degree, but there is little doubt that these crystals were not diamonds. Moissan's procedure is as follows:—200 grams of soft Swedish iron, cut up into cylinders 1 to 2 cm. long and about 1 cm. diameter, are placed in a carbon crucible and covered with sugar carbon. The crucible is then heated in the electric furnace to a temperature of about 3,000° C., and is then quickly plunged into a vessel full of cold water. The crucible and the contained metal remain red-hot for several minutes, owing to the water near the crucible assuming the spheroidal state; bubbles of gas rise to the surface of the water and burst without burning. The temperature sinks rapidly, the crucible becomes cold, and every gleam of light disappears: the experiment is then finished. This method utilises the large increase in volume undergone by iron in passing from the liquid to the solid condition; it has long been known that a "pig" of iron floats in a bath of the melted metal, thus showing that iron, like water, expands as it solidifies. In Moissan's experiment, the outer layer of iron solidifies first, so that the inner core solidifies under enormous pressure; under these conditions some of the carbon dissolved in the iron separates out in the form of small diamonds. The diamonds can be obtained by dissolving the iron in boiling hydrochloric acid, and then removing the amorphous carbon by heating to 200° in sulphuric acid containing small quantities of potassium nitrate; the denser carbon is then removed by fuming nitric acid containing potassium chlorate. After a last treatment with boiling hydrofluoric acid, followed by decantation with boiling sulphuric acid to destroy the fluorides formed, the residue is washed and dried, and the high density particles separated by bromoform. The small residue found at the bottom of the bromoform is washed with ether and placed in a tube containing methylene iodide; a few transparent crystals sink, while some black fragments float on the liquid. These crystals, therefore, possess densities between 3·0 and 3·5; they are mostly diamonds. To prove that they are really diamonds, it was necessary to show that they scratch the ruby, and produce carbon-dioxide on combustion. The largest diamonds yet produced are about 0·38 mm. in diameter. The third, fourth, and fifth chapters deal with the preparation of various elements and compounds in the electric furnace; the fifth chapter, in particular, deals with recent researches in which the carbides of neodymium, praseodymium, and samarium, the silicides of vanadium and cerium, and the borides of silicon have been obtained.

A Text-Book on Steam and Steam Engines, including Turbines and Boilers. By Andrew Jamieson, M.I.C.E. Fourteenth edition, revised. pp. xxiv. + 780, with 400 illustrations to the text, and 11 special plates. (London: Charles Griffin & Co., 1904.) Price 10*s.* 6*d.*

Professor Jamieson's books are old favourites with engineering students; it is therefore unnecessary to give a detailed account of the above book, further than to say that many of the chapters have been re-written, so as to bring them up to date, while the whole has been recast, re-paged, and carefully re-indexed. The latest kinds of pyrometers and calorimeters are described, and special attention has been given to the fundamental principles of heat and thermo-dynamics. The latest types of indicator, with diagrams from simple, compound, triple and quadruple expansion reciprocating engines, are described and discussed. A clear explanation is given of Amsler's planimeter and its use. The Corliss engine and various types of steam turbine receive due attention, their suitability for electric lighting plants being ably discussed. A number of questions from Board of Education and City and Guilds examination papers are appended. All questions which have yet been set by the Institution of Civil Engineers, on the "Theory of Heat Engines," for their Associate Membership, are given in an appendix.

Elementary Manual of Applied Mechanics; specially arranged for the use of First-Year Board of Education, City and Guilds of London Institute, Colonial and other Engineering Students. By Andrew Jamieson, M.I.C.E. Sixth edition, revised

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and enlarged. pp. xvi. + 345. (London: Charles Griffin & Co., 1904.) Price 3*s.* 6*d.*

The chief changes effected in this popular manual are that notes on scalar and vector quantities have been inserted in Lecture I., and the questions set during the last dozen years at the Board of Education examinations have been appended. As a frontispiece, an excellent reproduction is given from a photograph of a modern turret lathe, made by Messrs. Herbert, Ltd., of Coventry; working drawings of this lathe are given in Lecture XVI. There is little doubt that the present edition will maintain the popularity accorded to former editions of the same work.

The Phase Rule and its Applications. By Alex. Findlay, M.A., Ph.D., D.Sc. Together with an **Introduction to the Study of Physical Chemistry. By Sir William Ramsay, K.C.B., F.R.S.** pp. lxiv. + 313, with 118 illustrations in the text. (London: Longmans, Green & Co., 1904.) Price 5*s.*

Towards the end of the last century, important advances were associated with the introduction of physical methods of investigation into chemistry. At the present day there is a wide field of research and theory which is so far under the dominion of physics that its fundamental principles are based on the laws of thermo-dynamics, while its allegiance to chemistry is based on the fact that its investigations are concerned with the particular properties of the elements and compounds, and not with the general properties of matter. In the Introduction * to the above work, written by Sir William Ramsay, a lucid account is given of the aim and scope of physical chemistry; from this it will be seen how much our knowledge of to-day has been extended by the investigators who have devoted themselves to this branch of science. One of the most important steps was made by Professor Willard Gibbs when he established the so-called Phase Rule, which is discussed in the volume before us. The Phase Rule is a law of chemical equilibrium, which can be most easily explained by considering the equilibrium of water, ice, and aqueous vapour in a space empty but for the presence of these substances. Water, ice, and aqueous vapour are said to constitute separate *phases* of the chemical compound possessing the symbol H_2O. At one particular temperature and pressure, the ice, water, and vapour can exist in equilibrium side by side; but in general, only two of these substances can exist in equilibrium in the same vessel. At a temperature above that corresponding to the "triple point," water will evaporate into the initially empty space above it until the pressure of the vapour attains a certain value; when this pressure is attained, no further evaporation occurs. Dr. Findlay ably traces the similarity between the above phenomena and those met with in chemical reactions: in many of these the velocity of reaction decreases after a time, so that the reaction is never completed, a state of "dynamical equilibrium" being established—that is, a state in which two equal and opposite reactions occur simultaneously to equal extents, as for instance, when two given substances simultaneously combine and dissociate at equal rates. The student wishing to become acquainted with this important branch of physical chemistry is recommended to procure and study Dr. Findlay's book.

* This Introduction can be bought separately, price 1*s.* net.

Electro-Chemistry: Part 1, General Theory. By R. A. Lehfeldt, D.Sc. Including a chapter on the Relation of Chemical Constitution to Conductivity. By T. S. Moore, B.A., B.Sc. pp. ix. + 268, with 55 illustrations in the text. (London: Longmans, Green, & Co., 1904). Price 5*s.*

The science of Electro-Chemistry has developed wonderfully during the last twenty years, and a book on this subject by a writer who has distinguished himself in electro-chemical researches is sure to be cordially welcomed. The present volume deals merely with the general theory of electrolysis. Another volume by the same author is promised, in which the most important applications of the theory to primary and secondary cells, to electrolysis, and to the solution of chemical problems will be discussed. There are still some distinguished physicists and chemists who do not subscribe to the dissociation theory of electrolysis; to these, perhaps, Dr. Lehfeldt's unhesitating acceptance of the dissociation theory will appear rash, but it must be admitted that those who have accepted the dissociation theory have enriched our knowledge with discoveries which could hardly have been made by those resting content with the older theories. There appears to be little doubt that the dissociation theory will ultimately prevail, although certain difficulties still need explanation, and even some slight degree of modification may be anticipated.

The first chapter deals with the mechanism of conduction in electrolytes, and includes, amongst other matter, a discussion of the phenomena occurring at the electrodes, the migration of the ions, equivalent and ionic conductivities, Arrhenius's theory of dissociation, the law of dilution, and electrical conduction in fused salts. The second chapter, by Mr. T. S. Moore, deals with the relation between the chemical constitution of substances and their conductivities in solution. On this subject complete knowledge has not yet been obtained, but a close examination of experimental results has led to the detection of many interesting regularities. The third chapter is devoted to the study of chemi-electromotive force: due attention is given to the phenomena of concentration and polarisation, and the various thermo-dynamic theories are succinctly discussed; the chapter ends with a description of methods of measurement employed in electro-chemical researches.

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ANSWERS TO QUERIES.

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

COMBUSTION. — What use has been made of metallic aluminium for isolation of other metals? The heat of combustion of aluminium per gram is 7250, of sodium 2170, and of carbon 8000 calories. From these data determine whether it is possible to reduce aluminium or sodium from their oxides by carbon, or aluminium by sodium. —(*Honours Chemistry*, 1903.)

Aluminium, in the molten condition, acts in an extremely energetic manner on most oxides, including many which otherwise can only be reduced in the electric furnace. In practice aluminium is usually employed in the form of filings or powder, which is intimately mixed with the calculated quantity of the oxide to be reduced, the mixture being tightly packed into a crucible of resistant character — a Hessian crucible is often used. The reaction can be started by inserting a plug made of mixed barium peroxide and magnesium powder, which is easily set fire to, and by the high temperature thus produced, the whole mass in the crucible is ignited. The reduction is usually associated with a very large evolution of heat, and it is stated that a temperature approaching 3,000° may be attained.

The reduced metal is molten, and sinks through the fluid (but less dense) aluminium oxide produced; after cooling and solidifying the metal can usually be separated from the non-metallic portion of the mass, sometimes in well-formed crystals. It should be added that experiments on small quantities, involving (say) only a few ounces of the mixture, are less likely to be successful than operations on a large scale. By this process, manganese and chromium, for example, may be obtained from their oxides without difficulty.

The heat evolved in the interaction of iron oxide and aluminium powder is occasionally made use of to raise iron and steel bars or rails to a red or white heat, at inconvenient distances from a suitable forge.

In the second part of the question, a calculation of the heat evolved in the reactions represented by the equations 1, 2, and 3 is required.

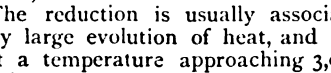
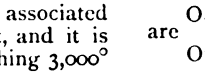
$$Al_2O_3 + 3C = 2Al + 3CO \quad \ldots\ldots(1)$$

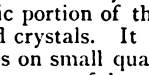
$$Na_2O + C = 2Na + CO \quad \ldots\ldots(2)$$

$$Al_2O_3 + 6Na = 2Al + 3Na_2O \quad \ldots(3)$$

Taking the quantities involved to be gram molecules or gram atoms throughout, in (1) the change from left to right represents the oxidation of 3 × 12 grams of carbon, which is accompanied by the evolution of 3 × 12 × 8000 = 288,000 gram-calories; from right to left, the oxidation of 2 × 27 grams of aluminium is indicated, which represents a heat evolution of 2 × 27 × 7250 = 391,500 gram-calories. On the whole, therefore, the heat change during the reduction would be 288,000 − 391,500 = − 103,500 gram-calories; in other words, there would be a large heat absorption, which renders it most unlikely that the reduction could be effected at all. Similarly in (2) a heat change of 12 × 8,000 − 2 × 23 × 2170 = (96,000 − 99,820) or − 3820 gram-calories is involved, and in (3) 6 23 × 2170 − 2 × 27 × 7250 = (299,460 − 391,500), or − 92,040 gram-calories. In all these cases, therefore, the inference is that it would not be possible to effect the reductions.

CONSTITUTIONAL FORMULÆ.—Discuss the constitution of the following groups of salts: — (*a*) sulphites, (*b*) hyponitrites, (*c*) persulphates, (*d*) periodates.—*Board of Education*. *Honours*, 1904.

(*a*) The possible formulæ of sulphurous acid are  and  from one or both of which, by replacement of hydrogen by metals or positive radicles, the salts may be derived. It is generally supposed that the salts are derived from the first, or asymmetric formulæ, and for several reasons.

The symmetrical esters of sulphurous acid, *e.g.*,  , are only to be obtained by the action of $SOCl_2$ or S_2Cl_2 on the alcohols; treatment of silver sulphite with ethyl iodide yields ethyl ethanesulphonate $C_2H_5.SO_2.OC_2H_5$. However, there is much to be said against arguments based on such observations, as many cases are known where such replacements are apparently indirect.

Support for the asymmetric formulæ of the sulphites is found in the statement that the neutralisation of sodium hydrogen sulphite by potassium hydroxide affords a salt not identical with that formed when potassium hydrogen sulphite is treated with sodium hydroxide. This statement, however, involves an inherent improbability so great that careful repetition of the work is very desirable.

The alkaline character of the normal sulphites of the alkali metals has been adduced in favour of an asymmetric constitution; this is in reality a matter of no moment, since the salts of many feeble dibasic and polybasic acids of undoubted

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hydroxylic character behave in a similar way; and the case of trisodium orthophosphate, which in aqueous solution is largely decomposed into disodium hydrogen phosphate and sodium hydroxide, is a well-known instance.

The problem of the constitution of the sulphites, therefore, may still be regarded as unsolved.

(*b*) The hyponitrites are derived from a weak dibasic acid, the composition and molecular weight of which is expressed by the formula $N_2O_2H_2$.

There are various graphic formulæ by which a substance of this composition may be represented; of these, the following, which are the least far-fetched, may be considered :—

(1) $NH_2{\cdot}NO_2$ (2) $NH:NO{\cdot}OH$

(3) $N:N(OH)(OH)$ (4) $\begin{matrix}\cdot\cdot\\ N{\cdot}OH\end{matrix}$
$\begin{matrix}\cdot\cdot\\ N{\cdot}OH\end{matrix}$

Judging from our knowledge of organic compounds which contain the group $\cdot NH\cdot NO_2$, the compound labelled (1) would be neutral; (2) would be a monobasic acid; (3) would probably be a strong base, containing, as it does, an $\cdot OH$ group attached to a quinquivalent nitrogen atom; (4) contains, twice over, the $:N\cdot OH$, or oximino group, which exhibits weak acid properties, and therefore would doubtless represent a weak dibasic acid, yielding a normal sodium salt with an alkaline reaction; moreover, the formula explains, readily enough, the formation of water and nitrous oxide from hyponitrous acid, which is usually represented as $\begin{matrix}\cdot\cdot\\ N\\ \cdot\cdot\\ N\end{matrix}>O$.

The existence of the isomeric acid $N_2O_2H_2$, which has been obtained from nitrourethane, is also easily accounted for on the view in use for expressing the difference between isomeric oximes; this assumes a different stereoisomeric arrangement of the atoms in the molecule, and the two isomers of the formula $N_2O_2H_2$ may be assigned the formulæ

$\begin{matrix}\cdot\cdot\\ N{\cdot}OH\\ \cdot\cdot\\ N{\cdot}OH\end{matrix}$ and $\begin{matrix}\cdot\cdot\\ HO{\cdot}N\\ \cdot\cdot\\ N{\cdot}OH\end{matrix}$

(*c*) The persulphates are derived from a dibasic acid $H_2S_2O_8$, and the formation of the latter during the electrolysis of sulphuric acid is usually assumed to be due to the coalescence of discharged HSO_4 ions, in pairs, at the positive electrode.

Assuming, as is most probable, that such ions may be represented as $SO_2(OH)(O-)$ the coalescence of a pair (assuming no deep structure change took place) would yield an acid having the constitution

$$\begin{matrix}SO_2(OH)(O)\\ |\\ SO_2(O)(OH)\end{matrix}$$

Now, by a process of hydrolysis, the persulphates yield a new acid of far more active oxidising properties than persulphuric acid itself; this could be most easily accounted for if, in the latter, the available oxygen is occupied in uniting the two parts of the persulphate molecule, whilst in the new acid it is free. The formula suggested for persulphuric acid explains how this might occur :—

$$\begin{matrix}SO_2(OH)(O)\\ |\\ SO_2(O)(OH)\end{matrix} + H_2O = SO_2(OH)(OH) + SO_2(O-OH)(OH)$$

as the unstable complex $-O-O-$ is represented in the way described, whilst in the supposed hydrolytic product $SO_2(O-OH)(OH)$ it appears to be available for immediate use.

[N.B.—It is not improbable that the true constitution of the hydrolytic product may be more complex than above represented, *e.g.*, $HO\cdot O\cdot SO_2\cdot O\cdot SO_2\cdot O\cdot OH$.]

(*d*) The periodates are derived from an acid H_5IO_6 of which the anhydride has the formula $(2H_5IO_6 - 5H_2O) = I_2O_7$. In this substance, and therefore in the periodates, it is quite legitimate to assume the presence of septavalent iodine, judging from the position of iodine in the periodic system.

The acid, then, may be considered as a partially dehydrated compound formed by removal of $1H_2O$ from $I(OH)_7$; hence its constitution may be expressed in the graphic form

$O:I(OH)(OH)(OH)(OH)(OH)$ or $O:I(OH)_5$, from which the corresponding formulæ of the periodates may be at once derived.

BLUE PRINTS, ETC.—Would you please inform me of the best books explaining :—1st, the Ferro-prussiate process, *i.e.*, white lines on blue ground; 2nd, Ferro-gallic process (blue on white); 3rd, Brown lines on white ground. Can you let me have the chemical changes which occur in each case? Also any chemical which will change the resultant ground colour to the same as that of the lines.

The best authority you could consult on this subject is the "British Photographic Almanac" for 1900, page 994. You would also pick up much useful information from "The Elementary Chemistry of Photographic Chemicals," by C. Sordes Ellis, published by Hazell, Watson, and Viney, Ltd.

The subject is scientifically dealt with in Professor Meldola's book, "Chemistry of Photography" (Nature Series, MacMillan and Co.), and "Chemistry for Photographers," by C. F. Townsend, F.I.C. (Dawbarn and Ward).

The chemical changes which take place may be briefly stated as follows :—

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(1) White lines on a blue ground. When light falls on a ferric salt (which, in this process, is ferric ammonium citrate) in presence of organic compounds which are easily oxidised and which, therefore, act as reducing agents, a ferrous salt is produced. The potassium ferricyanide which is also present on the sensitised paper gives no coloration with a ferric salt, but with ferrous salts it forms a blue precipitate of ferrous ferricyanide (Turnbull's blue). The print is fixed by washing with water, since, by so doing, the remaining ferrous salt on the white lines is washed away. Caustic soda or sodium carbonate will change the blue ground to white.

(2) Black lines on a white ground. The sensitising solutions in this case are (1) 10 per cent. solution of gelatine ; (2) solutions of ferrous sulphate, tartaric acid, and ferric chloride, with excess of water. The developer consists of solutions of oxalic and gallic acids.

By the action of light, as in the previous case, the ferric salt is reduced, in presence of an organic compound (tartaric acid) to ferrous, which latter is not acted on by the gallic acid in the developer; but the portions of the sensitised paper which have not been exposed to light (*i.e.*, protected by the lines of the design), have still ferric salt present, which forms a black insoluble precipitate with gallic acid.

Any chemical which will oxidise the ferrous salt to ferric will change the white ground to black on re-developing the paper.

(3) Brown lines on white ground. If a piece of paper be immersed in a solution of one part of uranous nitrate in five parts of water, dried in the dark and exposed under a negative, a very faint print of the design is produced, which consists of uranous oxide. If the print be now immersed in a silver solution, the design at once becomes visible, since uranous oxide precipitates silver, as such, from its solutions. No silver is deposited where the light has not penetrated, and thus the uranous nitrate can be washed away. In this process, the ground cannot be made to assume the same colour as the lines, as can easily be seen.

Obernetter's process is much less expensive (though a little more complicated) than the above. It depends upon the fact that cupric chloride is reduced to cuprous chloride under the action of light. Paper is saturated with cupric and ferric chlorides, then exposed under the design (or negative) to light. It is then plunged into a solution of potassium sulphocyanide, and treated with red prussiate of potassium, which produces with cuprous salts a brown precipitate of copper ferricyanide.

TORQUE.—A wrought iron shaft is subjected simultaneously to a bending moment of 8,000 pound-inches, and to a twisting moment of 15,000 pound-inches. Find the twisting moment equivalent to these two, and the least safe diameter of the shaft? The safe stress against shearing to be taken at 8,000 lbs. per square inch. Prove clearly the formula you employ.—*Prof. Goodeve's "Principles of Mechanics," p. 362, No. 139.*

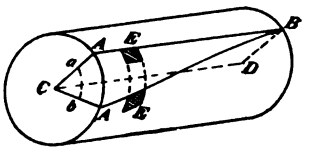

FIG. 1.—(TORQUE).

The application of a twisting moment to the shaft shown in Fig. 1 will cause every transverse section of the shaft to turn relative to one end, while remaining perpendicular to the axis ; the amount of rotation being proportional to the distance of the section from the end in question. Assuming the right end to be fixed, and the straight line A B to be one of the generators of the cylindrical surface in the untwisted condition, the application of the twisting moment will cause A B to be distorted as shown, and the little elementary rectangle E to be distorted into a rhombus. This distortion* produces tangential or shearing stresses of equal intensity over the faces of the little block of material which are perpendicular to the elementary area shown shaded. (The thickness of the block is supposed to be small.) The stresses over the faces F K and F J (Fig. 2) are called *companion shearing stresses*, because one cannot occur without the other. The same applies to the stresses over the two opposite faces.

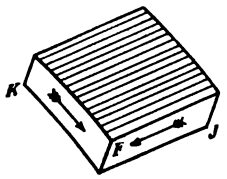

FIG. 2.—(TORQUE).

It should be noted that all planes parallel to that shown shaded (Fig. 2) are distorted, and that the planes over which the shearing stresses occur are perpendicular to one another *and* to the shaded plane (which may be called the plane of distortion). There is a similar relationship in an elementary block forming part of a piece of material subjected to a *bending moment.*

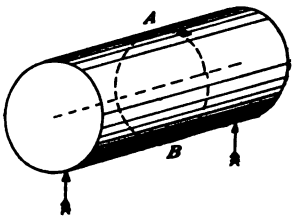

FIG. 3.—(TORQUE).

The same result is obtained wherever the little shaded area in Fig. 1 is situated on the surface of the shaft; but the amount of distortion and, consequently, the intensity of the shearing stresses, decrease from a maximum at the outer surface to zero at the axis of the shaft. Referring to Fig. 1, the displacement of the

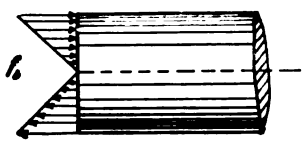
FIG. 4.—(TORQUE).

* The proof of this can be found in many text-books—*e.g.*, "Goodman's Applied Mechanics," p. 257 ; or "Lineham's Mechanical Engineering," p. 365.

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point A in the outer surface is A A, while the displacement of the point a is $a\,b$, and stress is proportional to strain.

Now consider the application of a bending moment to the shaft, or, in other words, treat it as a beam. At a transverse section A B (Fig. 3), there will be tensile and compressive stresses over the section as indicated in side elevation in

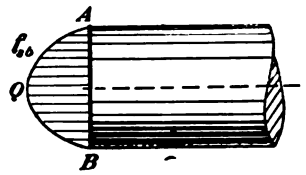

FIG. 5.—(TORQUE).

Fig. 4, the intensity of the stress at a point depending upon the distance of the point from the neutral surface. In Fig. 6, P Q R S is the central plane of flexure, that is, all movement takes place in planes parallel to this one. Also L M N O is the neutral surface, and the intensity of stress will be a maximum at A or B, and become less and less as the neutral surface is approached, and finally zero at the neutral

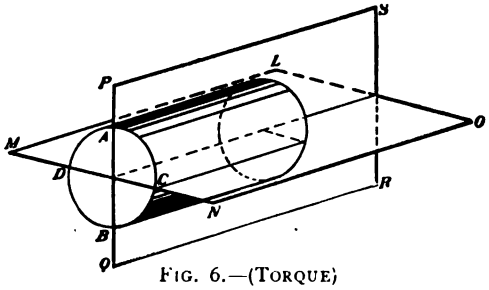

FIG. 6.—(TORQUE)

surface. Call this particular stress a *bending* stress, and indicate it by f_b (Fig. 4).

In addition to the bending action, there will be a shearing action over the transverse section A C B D. The consequent shearing stress at a point is given in Fig. 5 by the intercept between the curve A Q B and the line A B.*

It has already been mentioned that a single shearing stress cannot occur alone, but must be accompanied by another of equal intensity over a plane perpendicular to that of the former

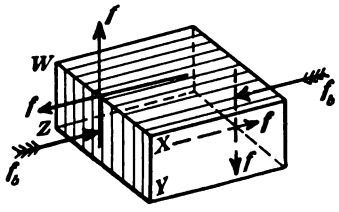

FIG. 7.—(TORQUE).
(For f in this diagram, *read* f_{sb}.)

* See "Goodman's Applied Mechanics," p. 319; or "Lineham's Mechanical Engineering," p. 923.

shear stress, and to the plane of distortion or movement. In Fig. 6, P Q R S is the plane of movement or distortion, and the plane of the shaft section is that of the primitive shearing stress; hence the plane of the companion shearing stress must be perpendicular to both the plane of section and the plane of flexure—that is, it must be horizontal.

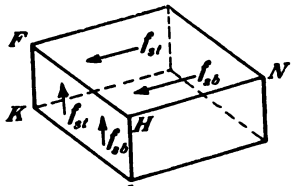

FIG. 8.—(TORQUE).

Summarising the above, we see that any elementary block in the shaft will be stressed as follows (see Fig. 7):—Bending stresses f_b, parallel with the axis of the shaft, over opposite faces, and shearing stresses f_{sb} over the faces shown shaded.

At a point A or B in the transverse section (Fig. 6), the bending stress is greatest and the shearing stress zero. At C or D the bending stress is zero, and the shearing stress greatest.

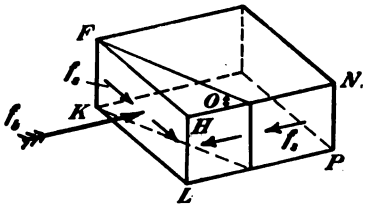

FIG. 9.—(TORQUE).

Now, considering the effect of both the bending and shearing actions together on an elementary block in the shaft at D (Fig. 6), we have shearing stress f_{st} per unit area (due to torsion) over the faces F N and F L (Fig. 8), and another shearing stress f_{sb} over the same faces due to bending, the resultant effect of these together being their sum. In most of the actual cases, f_{sb} is small compared with f_{st} and the sum of the two is seldom much greater than f_{st} alone.

If the block be considered at A in Fig. 6, there will then be a shearing stress f_{st} over the faces F L and H P (Fig. 9), together with a normal stress f_b over the face F L due to bending. There will be equal and opposite stresses over the opposite faces, but these will not be required in the following investigation. We now require to find what

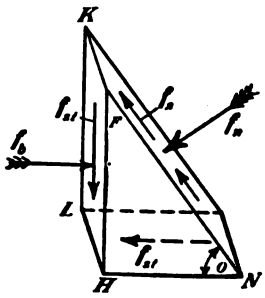

FIG. 10.—(TORQUE).

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is the effect of these stresses together, in producing stresses over a plane inclined to F L and L N, but perpendicular to the plane F N. Cut the block by a plane passing through F O. The part of the block on one side of the section must act on the other part with a resultant stress which can be resolved into a normal stress f_n and a tangential or shearing stress f_s over the inclined face or section (Fig. 10).

The total force over any face is the stress multiplied by the area of the face. Let the thickness L H or F K (Fig. 10) be called t. The total normal force over the face F L must be $f_b \cdot F H \cdot t$, and the total tangential force over the same face will be $f_{st} \cdot F H \cdot t$.

The triangular block of material (Fig. 10) is in equilibrium, hence the sum of the vertical and horizontal components of the forces on its faces must each be zero. Resolving vertically, and denoting the angle FNH by θ, we have

$$-f_{st} \cdot t \cdot FH + f_s \cdot t \cdot FN \sin\theta - f_n \cdot t \cdot FN \cos\theta = 0.$$

Resolving horizontally, we have

$$f_b \cdot t \cdot F H - f_{st} \cdot t \cdot HN \cdot - f_s \cdot t \cdot F N \cos\theta - f_n \cdot t \cdot F N \sin\theta = 0.$$

Dividing each of these equations by $t \cdot FN$ we have

$$f_n = (f_s - f_{st}) \tan\theta \quad . \quad . \quad . \quad . \quad (1)$$

$$f_s + f_{st} = (f_b - f_n) \tan\theta \quad . \quad . \quad . \quad . \quad (2)$$

Eliminating $\tan\theta$ from (1) and (2) we have

$$f_n(f_b - f_n) = f_s^2 - f_{st}^2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Solving for f_n and f_s we obtain

$$\left.\begin{aligned} f_n &= \tfrac{1}{2} f_b \pm \sqrt{f_{st}^2 - f_s^2 + \tfrac{1}{4} f_b^2} \\ f_s &= \sqrt{f_n(f_b - f_n) + f_{st}^2} \end{aligned}\right\} \quad . \quad . \quad (4)$$

From the former of these equations, we see that f_n increases as f_s diminishes. The latter cannot be negative, hence its least value is zero, and the maximum value of f_n occurs when f_s is zero. Substituting this value, we have

$$\text{max. } f_n = \tfrac{1}{2} f_b \pm \sqrt{f_{st}^2 + \tfrac{1}{4} f_b^2} \quad . \quad . \quad . \quad (5)$$

Let T = twisting moment,
B = bending moment,
r = radius of shaft,
I_1 = polar moment of inertia of section $= \frac{\pi}{2} r^4$

and I_2 = moment of inertia of section about a diameter $= \frac{\pi}{4} r^4$.

Then, using the elastic equations

$$\frac{T}{I_1} = \frac{f_{st}}{r} \text{ and } \frac{B}{I_2} = \frac{f_b}{r}$$

for separately twisting and bending a circular shaft, we obtain

$$f_{st} = \frac{T}{\frac{\pi}{2} r^3}, \text{ and } f_b = \frac{2B}{\frac{\pi}{2} r^3}$$

Substituting these in (5) we obtain

$$f_n \cdot \frac{\pi}{2} r^3 = B \pm \sqrt{T^2 + B^2} \quad . \quad . \quad . \quad (6)$$

The left-hand side is called the *simple equivalent twisting moment*, due to bending moment B and twisting moment T acting together.

Inserting the numbers given in the query, we have

$$\frac{\pi}{2} r^3 \times 8000 = 8000 \pm \sqrt{15000^2 + 8000^2}$$

from which $r = 1{\cdot}26$ inches.

It should be noted that the query states: "The safe stress against *shearing* to be taken as 8,000 lbs. per square inch," meaning f_n. But f_n is a *normal* stress, *i.e.*, a tensile or compressive stress, and hence the wording of the query is incorrect. The stress f_n is used in the expression (6) in a manner as if it were a shearing stress.

Although not required in the query, it may be noted that f_n may be expressed in terms of the original normal and shear stresses, and the inclination to the axis of the plane on which it acts. This may be done by eliminating f_s from (1) and (3), when we obtain

$$f_n \text{ (not necessarily a maximum)} = f_b \sin^2\theta - f_{st} \sin 2\theta \quad . \quad . \quad . \quad . \quad (7)$$

This will be a maximum when $\frac{d f_n}{d\theta} = 0$, *i.e.*, when

$$\frac{2 f_{st}}{f_b} = \tan 2\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Similarly, by eliminating f_n from (1) and (3), we have

$$f_s = \tfrac{1}{2} f_b \sin 2\theta - f_{st} \cos 2\theta \quad . \quad . \quad . \quad (9)$$

And this is a maximum when

$$\frac{2 f_{st}}{f_b} = -\cot 2\theta \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Equations (8) and (10) enable the planes of maximum normal and shear stresses to be located.

REPULSION MOTOR.—Briefly describe the modern form and mode of action of the single-phase repulsion motor, and sketch the curves of output, torque, and current, as functions of the speed (at constant frequency and terminal pressure) for such a motor. Discuss the suitability of the repulsion motor for railway work, and indicate how its performance may be improved.—(*City and Guilds Examination*, 1904. *Electric Lighting and Power Transmission. Honours, Section* 2.)

The repulsion motor is a type of single-phase alternating current commutator motor, possessing distinct primary and secondary circuits which have no electrical connection between one another. The primary or stator circuit is similar in construction to that of an induction motor, and in its simplest form consists of a laminated electro-magnet excited by means of the single-phase alternating current supplied, which produces a simple alternating magnetic field; whilst the secondary or rotor circuit is similar to the armature of a direct current machine, and is fitted with a commutator upon which press brushes which are connected together and short-circuited. The alternating magnetic field produced by the primary current induces armature currents in the conductors of

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the rotor circuits; these currents are organised by the short-circuiting or inter-connected brushes so as to give a definite polar displacement, as in the continuous current motor: in other words, the directions of the induced currents are controlled so that the coils carrying them tend to move out of the inducing field. The principle of action of the repulsion motor is an example of the repulsive effects, first announced by Professor Elihu Thomson, which exist when a plain copper ring is brought into the field of a solenoid excited by an alternating current.

The repulsion motor is thus a type of transformer possessing a secondary circuit movable relatively to the primary circuit, and it is essential that the plane of commutation of the permanently short-circuited brushes should be inclined at a certain angle with the plane of the primary coil. In many respects it is like a direct current motor, as indicated diagrammatically in Fig. 1, but there is this great difference, the pressure of supply in the case of direct current motors is to a certain extent limited, whilst in the case of the repulsion motor it is possible to adapt the primary winding for high pressure, and at the same time to design the secondary winding for pressures low enough to allow commutation to be effected satisfactorily, although the brushes are short-circuited.

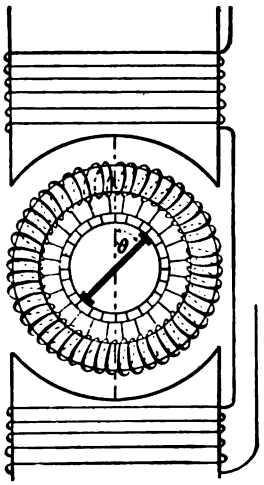

FIG. 1.–(REPULSION MOTOR).

If the brushes were placed so that the plane of commutation coincided with the direction of the field, the currents induced in the two sides of the armature would be equal and attain their maximum possible values, but their directions would be opposite; consequently no motion would be produced, since the tendency to produce rotation on the one side would be opposed to that on the other. If the plane of commutation were at right angles to the field axis no current would traverse the secondary circuit, and there would be no tendency to produce rotation. If the plane of commutation be inclined to the direction of the field axis, say at 45°, the maximum value of the armature current is not obtained, but the polar displacement is such that the secondary induced current acts upon the field due to the primary current, and gives rise to a torque, which retains its direction with the simultaneous reversal of the primary and secondary currents, according to the principles of electro-dynamic action, as in continuous current motors.

In general terms the repulsion motor may be said to possess many of the properties of a series-wound direct current motor; its characteristics are :—

(1) Maximum torque at starting.

(2) Increased torque with increase of current and decrease of speed.

(3) Comparatively constant efficiency through a wide range of speed.

It may be mentioned that in commercial repulsion motors the primary winding is distributed over an approximately uniformly-slotted core without projecting poles, as shown in Fig. 1. The characteristic properties of the repulsion are clearly exhibited in Fig. 2, the curves being plotted with revolutions per minute as a base. These curves have been taken from a paper by Mr. Walter I. Slichter, read before the American Institute of Electrical Engineers, January, 1904; they indicate that the repulsion motor is suitable for traction work, and it is found that the torque increases more rapidly with increasing current than in the series direct current motor, and also that the speed of the repulsion motor increases more rapidly with decreasing current than in the series motor. The repulsion motor, in fact, is admirably adapted for acceleration work, the efficiency of acceleration being higher than in direct current work, due to the possibility of obtaining fractional E.M.F.'s with alternating currents without increasing the dead resistance

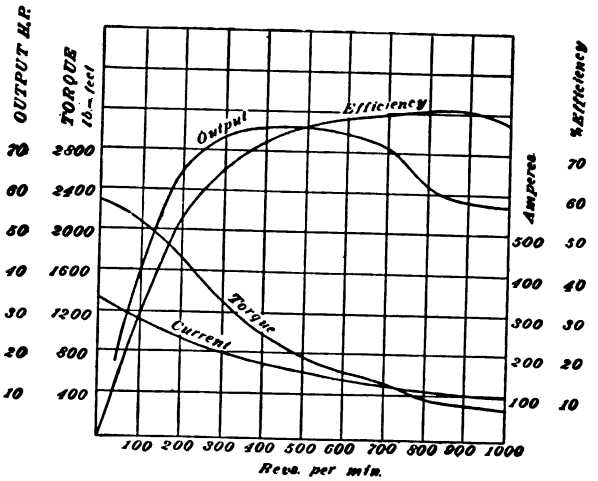

FIG. 2.—(REPULSION MOTOR).

losses of the direct current system of control. The greatest weakness in the working of this type of motor is the sparking at the short-circuiting brushes, and this is somewhat excessive at low speeds on account of the greater current in the short-circuited coils, and the tendency to heat and spark is then a serious matter. It is, in fact, in this direction that improvement must be effected if the

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repulsion motor is to become a serious rival to the direct-current series motor for traction purposes. The power factors are fairly satisfactory, but the efficiency might be improved. There are, however, as yet very scanty data to enable one to decide to what extent the repulsion motor is suitable for railway work, as it has not yet been put to the test of an actual trial other than that of shop tests. The curves given in Fig. 2 are taken from tests on a 60-h.p., 25-cycle, 500-volt motor.

ELECTROMAGNET.—Can you give me a formula or graph to determine the E.M.F. and number of turns required for an electromagnet of cast-iron for a strength of a given number of pounds per square inch ?

Example (1), What E.M.F. and number of turns would be required for a cast-iron magnet of 3-inch diameter for a strength of 200 pounds per square inch ? (2) If the E.M.F. = 100 volts, what number of turns would be required for magnet under same conditions ?

It is scarcely possible to give a single formula or even a graph which will enable our correspondent to construct an electromagnet for lifting purposes by simply taking into account the voltage applied and the number of turns of wire forming the winding. The problem of designing such an appliance is by no means a simple one, as will be obvious from the brief outline, given below, of the various steps which have to be taken into consideration when getting out the dimensions of the electromagnet.

According to Maxwell's law, the tractive force or pull exerted between two parallel magnetised surfaces is given by

$$P = \frac{A\,B^2}{8\,\pi} \text{ dynes} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where A is the area in square centimeters over which the magnetic flux is uniformly distributed, and B denotes the flux density or the number of lines of force per square centimeter, and P is the pull in dynes. If the tractive force or pull P is required in pounds weight, we have

$$P = \frac{A\,B^2}{8 \times \pi \times 981 \times 453{\cdot}6} = \frac{A\,B^2}{11{,}183{,}000} \text{ pounds} \quad (2)$$

It must, however, be noted that these formulæ are strictly applicable only when the distance between the attracting surfaces is small compared with their area, or when one surface extends considerably over the other. If the area of the core be given in square inches instead of square centimeters, then the tractive force is given by

$$P_1 = \frac{6{\cdot}45\,A_1\,B^2}{11{,}183{,}000} \text{ pounds} \quad . \quad . \quad . \quad . \quad (3)$$

where A_1 is the area in square inches, and the pull per square inch will be

$$\frac{P_1}{A_1} = \frac{6{\cdot}45}{11{,}183{,}000}\,B^2 = \frac{B^2}{1{\cdot}733{,}800} \text{ pounds.} \quad . \quad (4)$$

Since the function of the winding is to provide the magnetic flux when current is supplied, the next step is to design the magnetic circuit of the electromagnet, and here a considerable amount of experience is required. To simplify matters let us suppose that the magnet is only required for supporting a given weight, and that the body supported has not to be attracted through any distance. The horse shoe form of electromagnet (Fig. 1) will give the best results, and the difficulty of the problem centres about the determination of the length l of the magnetic circuit, the dimensions of the coil, and the space required for the coil, according to the conditions imposed and the voltage of the current supplied. To alter one condition or factor means most probably a new design throughout.

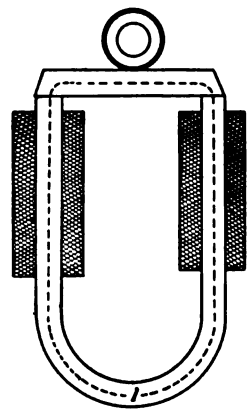

FIG. 1—(ELECTROMAGNET).

In the example represented in Fig. 1 the magnetic circuit is closed, and according to the laws of the magnetic circuit,

$$B = \frac{1{\cdot}257\,C\,T\,\mu}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where C is the current in amperes, T the number of turns of wire, μ is the permeability of the iron, and l is the length of the complete magnet circuit (shown dotted). Obviously l should be as short as possible ; but it must be long enough to offer space for the coils of wire as shown. The design of the coil is a special problem in itself, and for a given number of ampere-turns (C T) and voltage, there is a certain size of wire which will fill a given coil space. The connection between the size of wire to use and these factors is given by the formula

$$d \text{ (mils)} = \sqrt{\frac{12\,C\,T\,l_m}{E}} \quad . \quad . \quad . \quad . \quad (6)$$

in which E is the voltage and l_m is the mean length of a turn of the winding in feet.

From equation (6)

$$C\,T = \frac{E\,d^2}{12\,l_m}$$

and by substitution in equation (5),

$$B = 1{\cdot}257\,\frac{E\,d^2}{12\,l_m} \times \frac{\mu}{l}.$$

Substituting this value in equation (4), we obtain

$$\frac{P_1}{A_1} = \left(\frac{1{\cdot}257\,E\,d^2\,\mu}{12\,l_m\,l}\right)^2 \times \frac{1}{1{,}733{,}800}$$

$$= \frac{E^2\,d^4\,\mu^2}{158{,}000{,}000\,l_m^2\,l^2} \text{ pounds.}$$

The result shows that it is impossible to give a formula expressing the pull per square inch in terms of the voltage and the number of turns, unless the dimensions of the core and winding be known. If the dimensions can be obtained approximately from another electro-magnet of

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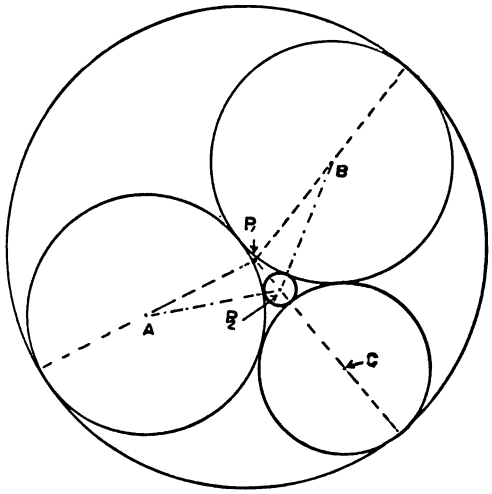

FIG. 1.—(QUADRIC).

similar capacity, equations (4), (5), and (6) will enable our correspondent to make the necessary calculations provided he has a curve of the magnetic properties of the core, which will supply him with the value of μ for the ampere turns used.

QUADRIC.—If a, b, and c be the radii of three circles which touch one another externally, and r_1 and r_2 be the radii of the two circles that can be drawn to touch these three, prove that :—

$$\frac{1}{r_2} - \frac{1}{r_1} = \frac{2}{a} + \frac{2}{b} + \frac{2}{c}.$$

—Loney's Trig., page 249, *ex.* 30.

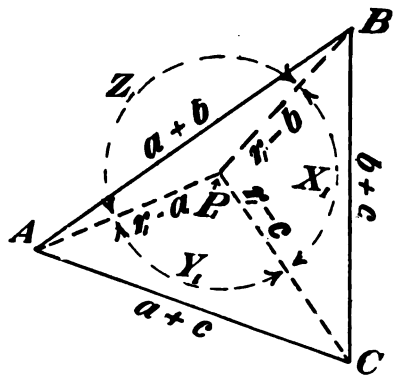

FIG. 2.—(QUADRIC).

Let A, B, C, P_1, and P_2 (Fig. 1) be the centres of the circles of radii a, b, c, r_1, and r_2. It will be seen at once that

$$P_1A = r_1 - a, \quad P_2A = r_2 + a.$$
$$P_1B = r_1 - b, \quad P_2B = r_2 + b.$$
$$P_1C = r_1 - c, \quad P_2C = r_2 + c.$$

(It will be noticed that the second set of equations can be derived from the first by changing the signs of a, b, and c.)

The lines joining P_1 to A, B, and C divide the original triangle ABC into three parts, and the sum of the angles at P_1 is 360°.

Denoting these angles by X_1, Y_1, Z_1, any trigonometrical identity connecting these angles will give a relation between r_1, a, b, and c, and the corresponding relation connecting r_2, a, b, and c can be deduced at once. A great many equations connecting r_1, r_2, a, b, and c can be formed : the following identity is established in many trigonometrical text-books

$$1 + 2\cos 2A \cos 2B \cos 2C = \cos^2 2A + \cos^2 2B + \cos^2 2C,$$

where $A + B + C = 180°$.

In our case this is

$$1 + 2\cos X_1 \cos Y_1 \cos Z_1 = \cos^2 X_1 + \cos^2 Y_1 + \cos^2 Z_1 \quad . \quad . \quad (1)$$

$$\text{Now } \cos X_1 = \frac{(r_1 - b)^2 + (r_1 - c)^2 - (b + c)^2}{2(r_1 - b)(r_1 - c)} = \frac{r_1^2 - r_1(b + c) - bc}{(r_1 - b)(r_1 - c)} = 1 - \frac{2bc}{(r_1 - b)(r_1 - c)} = (1 - \alpha) \text{ say.}$$

Similarly

$$\cos Y_1 = (1 - \beta) \text{ and } \cos Z_1 = (1 - \gamma)$$

where β and γ are derived from α by a cyclical change of letters.

On substitution in equation (1) we get

$$1 + 2(1 - \alpha)(1 - \beta)(1 - \gamma) = (1 - \alpha)^2 + (1 - \beta)^2 + (1 - \gamma)^2,$$

which reduces to

$$\alpha^2 + \beta^2 + \gamma^2 = 2(\alpha\beta + \beta\gamma + \gamma\alpha) - 2\alpha\beta\gamma.$$

On putting in the values of α, β, and γ, we obtain

$$4\left(\frac{b^2c^2}{(r_1 - b)^2(r_1 - c)^2} + \frac{c^2a^2}{(r_1 - c)^2(r_1 - a)^2} + \ldots\right) = 8\left(\frac{c^2ab}{(r_1 - c)^2(r_1 - a)(r_1 - b)} + \ldots\right) - 16\frac{a^2b^2c^2}{(r_1 - a)^2(r_1 - b)^2(r_1 - c)^2}.$$

$$\text{Hence } \frac{(r_1 - a)^2}{a^2} + \frac{(r_1 - b)^2}{b^2} + \frac{(r_1 - c)^2}{c^2} - 2\left\{\frac{(r_1 - a)(r_1 - b)}{ab} + \ldots\right\} + 4 = 0,$$

which reduces to

$$r_1^2\left(\frac{1}{a^2} + \frac{1}{b^2} + \frac{1}{c^2} - \frac{2}{ab} - \frac{2}{bc} - \frac{2}{ca}\right) + 2r_1\left(\frac{1}{a} + \frac{1}{b} + \frac{1}{c}\right) + 1 = 0.$$

By changing r_1 to r_2, and writing for a, b, c their negatives, we can deduce at once the connection between r_2, a, b, and c (or we may repeat the calculations *de novo*).

The relation is

$$r_2^2\left(\frac{1}{a^2} + \frac{1}{b^2} + \frac{1}{c^2} - \frac{2}{ab} - \frac{2}{bc} - \frac{2}{ca}\right) - 2r_2\left(\frac{1}{a} + \frac{1}{b} + \frac{1}{c}\right) + 1 = 0.$$

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Writing the coefficients of r_1^2 and r_1 as p and q, we obtain

$$\frac{1}{r_1^2} + 2q\frac{1}{r_1} + p = 0,$$

and $$\frac{1}{r_2^2} - 2q\frac{1}{r_2} + p = 0.$$

Solving these equations, and leaving out the negative values of $\frac{1}{r_1}$ and $\frac{1}{r_2}$. (p is negative), we obtain

$$\frac{1}{r_1} = -q + \sqrt{q^2 - p},$$

$$\frac{1}{r_2} = q + \sqrt{q^2 - p}.$$

Hence $\frac{1}{r_2} - \frac{1}{r_1} = 2q = 2\left(\frac{1}{a} + \frac{1}{b} + \frac{1}{c}\right)$.

DIFFERENTIAL EQUATIONS.—Show that solutions of $f\left(\frac{y}{x}, \frac{dy}{dx}\right) = 0$ are homogeneous in x, y and some power of a single constant, and conversely, that if the typical equation of a member of a family of curves be homogeneous in x and y and some power of one constant, the differential equation of the family is homogeneous and the family consists of similar curves. State which of the following families of curves are similar sets for different values of a and b:—

(1) $y^2 = 4ax$,

(2) $y = a\cosh\frac{x}{2}$,

(3) $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$,

(4) $y = 2a^3 \log\frac{x}{a^3}$,

(5) $b\tan^{-1}\frac{y}{x} = a + y$,

(6) $x^3 + y^3 = 3axy$,

giving reasons.

Given $f\left(\frac{y}{x}, \frac{dy}{dx}\right) = 0$ (1), we may suppose the equation solved for either $\frac{dy}{dx}$ or $\frac{y}{x}$. On the first supposition we should have an equation of the form

$$\frac{dy}{dx} = f_1\left(\frac{y}{x}\right) \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

Let $y = vx$, and (ii.) becomes, after reduction,

$$\frac{dv}{f_1(v) - v} = \frac{dx}{x},$$

and on integration we should have an equation of the form

$$f_2\left(\frac{y}{x}\right) = \log\frac{x}{c} \quad . \quad . \quad . \quad \text{(iii.)}$$

where $\log c$ is the arbitrary constant of integration.

Equation (iii.) may be supposed thrown into the form

$$\frac{y}{x} = f_3\left(\frac{x}{c}\right),$$

or, what is the same thing,

$$\frac{y}{c} = \frac{x}{c} f_3\left(\frac{x}{c}\right),$$

which denotes that $\frac{y}{c}$ is a function of $\frac{x}{c}$, or generally

$$F\left(\frac{x}{c}, \frac{y}{c}\right) = 0 \quad . \quad . \quad . \quad \text{(iv.)}$$

an equation homogeneous in x, y, and c.

The graphs of (iv.) corresponding to different values of c must be a set of similar curves, for any change in c simply changes the size, but not the shape of the curve.

Starting with (iv.), we may suppose the steps retraced until we come to

$$\frac{y}{x} = f_3\left(\frac{x}{c}\right) \quad . \quad . \quad . \quad . \quad \text{(v.)}$$

Differentiating this, we obtain

$$\frac{1}{x}\frac{dy}{dx} - \frac{y}{x^2} = f_3'\left(\frac{x}{c}\right) \times \frac{1}{c},$$

and $\therefore$ $$\frac{dy}{dx} - \frac{y}{x} = \frac{x}{c} f_3'\left(\frac{x}{c}\right).$$

But from (v.) $\frac{x}{c}$ can be expressed as a function of $\frac{y}{x}$, and therefore

$$\frac{dy}{dx} - \frac{y}{x} = f_4\left(\frac{y}{x}\right),$$

which says $\frac{dy}{dx}$ is a function of $\frac{y}{x}$, and generally, therefore,

$$f\left(\frac{y}{x}, \frac{dy}{dx}\right) = 0.$$

The set of curves for which $f\left(\frac{y}{x}, \frac{dy}{dx}\right) = 0$ is the differential equation are similar, for if we imagine any radius vector drawn making an angle θ with the axis of x, then $\frac{y}{x} = \tan\theta$, and $\frac{dy}{dx}$ is the slope of the curve, and (i.) tells us that $\frac{dy}{dx}$ depends on θ only, and not on the particular curve of the set we may be considering. In other words, the curves are all parallel where any one radius vector cuts them.

(1) $\left(\frac{y}{a}\right)^2 = 4\frac{x}{a}$, of form (iv.).

(2) $\frac{y}{a} = \cosh\frac{x}{2}$, not homogeneous in x, y, and a.

On differentiating and eliminating a, we find $\frac{dy}{dx} = y\tanh\frac{x}{2}$, non-homogeneous in x and y.

(3) On changing a and b, the changes in x and y will obviously not be proportional, and we shall not get similar curves (unless $b = a$).

(4) $\frac{y}{a^3} = \log\left(\frac{x}{a^3}\right)^2$ form (iv.).

(5) Not of form (iv.). On differentiation we obtain $\frac{dy}{dx} = \frac{y}{x} + \frac{x}{b}\left(1 + \frac{y^2}{x^2}\right)$ not of form (i.).

(6) $\left(\frac{x}{a}\right)^3 + \left(\frac{y}{a}\right)^3 = 3\frac{x}{a}\cdot\frac{y}{a}$ of form (iv.).

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NAVAL ARCHITECTURE.—Will you please give me a complete proof of the following formula for finding the work done by a bilge keel to a ship in a single swing. Work done

$$= \text{area of bilge keel} \times r^3 \times \frac{4\pi^2}{3T^2} \times \theta^3 \times c_2$$

where T = period for a single swing, 2θ = arc of oscillation, and c_2 is determined by experiment, which is given on page 178 of White's "Naval Architecture."

According to the ordinary assumptions, the equation to the rolling motion of a ship is

$$\frac{d^2\theta}{dt^2} + \frac{g}{K^2} \cdot m\theta = 0$$

where K is the radius of gyration of ship, and m is the metacentric height. On working this equation out, we arrive at the time of a single oscillation

$$T = \pi\sqrt{\frac{K^2}{m.g}},$$

and it is seen that the motion of the ship is given by

$$\theta = \Theta \sin \frac{\pi}{T} \cdot t,$$

Θ being maximum angular deflection.

Now, with respect to the bilge keel, Mr. Froude found that a wholly immersed plane moving normal to itself experiences a resistance R given by

$$R = c \cdot A \cdot v^2,$$

where A = area in sq.-ft.
v = speed f.s.
c = coefficient.

In the case of a bilge keel, v in this formula is $r \cdot \frac{d\theta}{dt}$ where r is a mean radius and $d\theta/dt$ is the angular velocity, so that

$$R = c \cdot A \cdot r^2 (d\theta/dt)^2.$$

The moment of this resistance is

$$c \cdot A \cdot r^3 (d\theta/dt)^2.$$

Now, from the above

$$\theta = \Theta \sin \frac{\pi}{T} \cdot t,$$

and $$d\theta/dt = \Theta \frac{\pi}{T} \cdot \cos \frac{\pi}{T} \cdot t.$$

from which $$(d\theta/dt)^2 = \frac{\pi^2}{T^2}(\Theta^2 - \theta^2).$$

The moment of resistance at angle θ is

$$c \cdot A \cdot r^3 \frac{\pi^2}{T^2}(\Theta^2 - \theta^2),$$

and the work in passing from Θ_1 to o is given by

$$\int_o^{\Theta_1} c \cdot A \cdot r^3 \frac{\pi^2}{T^2}(\Theta_1^2 - \theta^2) \cdot d\theta,$$

and from Θ_1 port to Θ_2 starboard

$$\frac{4}{3} \cdot c \cdot A \cdot r^3 \cdot \frac{\pi^2}{T^2} \cdot \Theta_m^3$$

where $\Theta_1^3 + \Theta_2^3$ is taken as equalling $2\,\Theta_m^3$, where Θ_m is the mean arc of oscillation.

In addition to the book mentioned, reference is made to the theory of rolling in "Shipbuilding" article in the new "Encyclopædia Britannica," and also in Attwood's "Warships."

STATICS.—A number of equal weightless rods are freely jointed, and assume the form of a regular polygon, when subjected to a system of forces at each joint, all emanating from a point on the circumscribing circle. Show that, if from a point radii be drawn to represent in magnitude and direction the stresses in the rods, and a polygon be constructed so that its sides, taken in order, represent the system of applied stresses, the polygon will be equiangular and described about a parabola, and further, the angular points of the polygon will all be on a hyperbola.—(*Greaves' Statics, p.* 117.) Give the geometrical and analytical solutions.

The question does not give any connection between the radii to be drawn and the polygon to be constructed, but we may suppose that the whole figure to be drawn constitutes the *stress diagram* for the given regular polygonal framework and the applied forces.

If P be the point of concurrence of the applied forces, A, B, . . . N the vertices of the given polygon of n side, then (P being between A and N), the angles between P A, P B, etc., are each equal to $\frac{\pi}{n}$, and that between P N and P A is

$$2\pi - \frac{n-1}{\pi}\pi = \pi\left(\frac{n+1}{n}\right).$$

Denoting by $a, b, c, \ldots n$ the sides of the stress diagram corresponding to P A, P B . . . we see that the *acute* angles between a and b, b and c, etc., will be π/n, which is also the acute angle between the sides n and a. The lines $a, b, c \ldots$ will *not*, however, in general, form an equi-

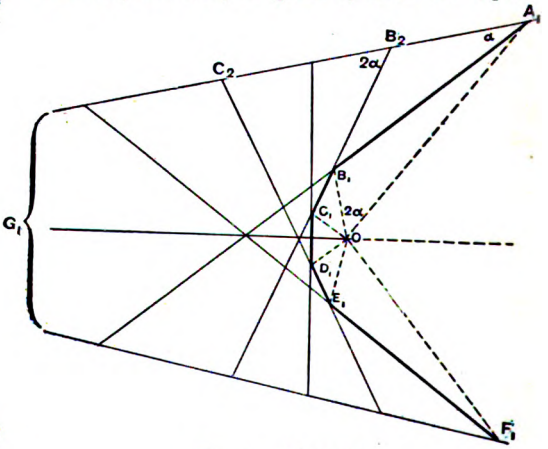

FIG. 1.—(STATICS).

angular polygon. If they do, then the sum of the exterior angles must be either

$$n \times \frac{\pi}{n} \text{ or } n \times \frac{n-1}{n}\pi,$$

but the sum must be 2π for an equiangular polygon, hence $n = 3$. If then $n > 3$, the lines $a, b \ldots$ must form a re-entrant polygon.

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The figure given below is the stress diagram for a seven-sided regular polygonal framework under forces as in question. The lines OA_1, OB_1, ... OG_1 represent the stresses in the bars of the frame, while A_1B_1, B_1C_1, ... F_1G_1 and G_1A_1 represent the forces applied at the joints. Although the figure is drawn for seven sides, it will be seen that the argument can be at once generalised.

In the figure the lines A_1B_1, B_1C_1, etc., are produced to cut the lines A_1G_1 and F_1G_1.

From the method of construction it is evident that quadrilateral $OB_1B_2A_1$ has the angles at O and B_2 supplementary, hence the points are concyclic.

Now, a parabola is determined by two tangents and the focus, hence O, A_1B_2, and A_1B_1 determine a parabola. To find the direction of a second tangent from B_1 we use the property "the vertices of a circumscribing triangle to a parabola are conclyclic with the focus." Hence, the construction to find the second tangent from B_1 gives us B_1B_2, and, therefore, B_1C_1 touches the same parabola. Similarly, taking A_1B_1 and B_1C_1 as the tangents and O the focus, we can show that C_1D_1 is a tangent. Hence, all the tangents circumscribe a parabola.

The same result may be found analytically by obtaining the equations to B_1A_1 etc., in polar co-ordinates, O being the origin, and OG_1 the initial line, and showing that it is of the form

$$\frac{l}{r} = \cos\theta + \cos(\theta - \alpha).$$

That the points $A_1, B_1, \ldots$ are on a hyperbola is a particular case of the general theorem :—

"The locus of the intersections of tangents to a parabola which intersect at a constant angle is a hyperbola." The analytical proof is as follows :—

$\frac{l}{r} = 1 + \cos\theta$ being the polar equation to a parabola, then

$$\frac{l}{r} = \cos\theta + \cos(\theta - \beta)$$

$$\frac{l}{r} = \cos\theta + \cos(\theta - \gamma)$$

are tangents at the points whose vertical angles are β and γ. The vectorial angles of the perpendicular from the origin on these tangents are $\frac{\beta}{2}$ and $\frac{\gamma}{2}$. Hence, the angle between the tangents is

$$\frac{\gamma - \beta}{2} = \alpha$$

At the point of intersection of the tangents we have

$$\cos(\theta - \beta) = \cos(\theta - \gamma),$$

or $$2\sin\left(\theta - \frac{\beta + \gamma}{2}\right)\sin\frac{\beta - \gamma}{2} = 0.$$

Hence, $$\theta = \frac{\beta + \gamma}{2},$$

and $$\alpha = \frac{\beta - \gamma}{2}.$$

Hence $$\theta + \alpha = \beta,$$

and $$\frac{l}{r} = \cos\theta + \cos\alpha,$$

or $$\frac{l\sec\alpha}{r} = 1 + \sec\alpha\cos\theta.$$

Now, $\sec\alpha > 1$, and writing $e = \sec\alpha$ and $L = l\sec\alpha$, we have

$$\frac{L}{r} = 1 + e\cos\theta,$$

the polar equation of a hyperbola having 0 as one focus.

Geometrically we can prove the above result by noticing that A_1B_2, B_2C_2, subtend equal angles at the focus, and applying the method of reciprocal polars to the theorem, "If a chord of a circle subtends a constant angle at a fixed point on the curve, the chord always touches a circle."

STRAIN. — Show that for a cylindrical mild steel shell (Poisson's ratio $\frac{1}{4}$) subject to internal pressure, the real maximum strain is $\frac{7}{8}$ of the strain due to the maximum tensile stress. Neglecting the joints, find the increase in diameter of a cylindrical steel shell 4 feet in diameter, $\frac{3}{8}$ in. thick, due to an internal gauge pressure of 100 lbs. per sq. in. Take E = 13,500 tons per sq. in. — *London University, B.Sc. (Engineering)*, 1904.

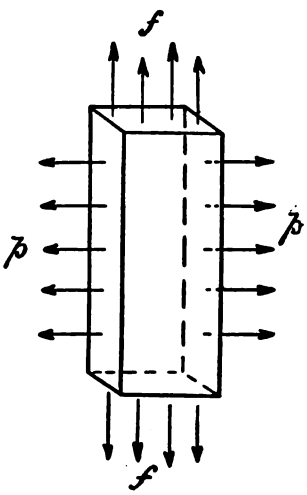

FIG. 1.—(STRAIN).

If a piece of homogeneous material be subject to stresses f tons per sq. in. over a pair of opposite faces (Fig. 1), the corresponding longitudinal strain parallel to the direction of stress will be $\frac{f}{E}$, and the lateral strain perpendicular to f and parallel to the direction of the other two rectangular axes will be $\left(-\frac{f}{mE}\right)$ where m is Poisson's ratio.

Similarly, the strains due to the stress of p tons per sq. in. will be $\frac{p}{E}$ parallel to p, and $-\frac{p}{mE}$ parallel to the other axes.

Adding together the respective strains parallel to the three axes, we obtain

$$\frac{f}{E} - \frac{p}{mE} \text{ parallel to } f,$$

$$\frac{p}{E} - \frac{f}{mE} \text{ parallel to } p,$$

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and $-\frac{p}{mE} - \frac{f}{mE}$ parallel to the third axis.

In the case of the boiler shell (Fig. 2), the circumferential stress is f, and the axial stress is p tons per sq. in. We know that $f = 2p$; hence we may write the above as

Resultant strain parallel to f

$$= \frac{f}{E}\left(1 - \frac{1}{2m}\right) = \frac{7}{8}\frac{f}{E},$$

resultant strain parallel to p

$$= \frac{f}{E}\left(\frac{1}{2} - \frac{1}{m}\right) = \frac{1}{4}\frac{f}{E},$$

resultant strain perpendicular to f and p

$$= -\frac{f}{E}\left(\frac{1}{m} + \frac{1}{2m}\right) = -\frac{3}{8}\frac{f}{E}.$$

Now $\frac{f}{E}$ is the strain corresponding to f, the maximum tensile stress in the material due to internal pressure, the boiler being considered as a thin cylinder. Call this the nominal strain; then

$$\frac{\text{real strain}}{\text{nominal strain}} = \frac{\frac{7}{8}\frac{f}{E}}{\frac{f}{E}} = \frac{7}{8},$$

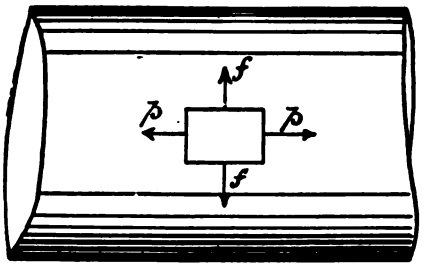


FIG. 2.—(STRAIN).

or the real strain is $\frac{7}{8}$ths of the strain due to the maximum tensile stress in the material.

From the thin cylinder we have

ft = pressure per sq. in. × radius of cylinder,

where t = the thickness of shell.

Then

$$f = \frac{100 \times 24}{\frac{3}{8}} = 6{,}400 \text{ lbs. per sq. in.}$$

Real maximum strain $= \frac{7}{8}\frac{f}{E}$

$$= \frac{7}{8} \times \frac{6400}{2240} \times \frac{1}{13500}$$

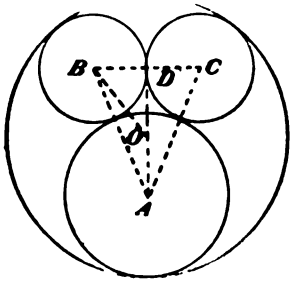
$$= \frac{1}{3400}$$

$$= \frac{\text{increase of diameter}}{\text{original diameter}},$$

hence the increase of diameter $= \frac{48}{5400} = 0{\cdot}0089$ inch.

GEOMETRY.—Three circles, two of which are equal in diameter, touch one another. Find an expression, giving the diameter of the smallest circle, which will enclose all three.

Let A, B, C be the centre, a, b, and c the radii of the given circles; O the centre, and r the radius of the required circle.



Assuming that the smallest circle enclosing circle is the one touching the three given circles, we have from the figure

AB = AC = $a + b$,

BC = $2b$,

OA = $r - a$; and OB = OC = $r - b$.

Since BOD and BAD are right-angled triangles, we have

$$OD^2 = (r - b)^2 - b^2 = r^2 - 2br,$$

$$AD^2 = (a + b)^2 - b^2 = a^2 + 2ab.$$

Hence $AO = \sqrt{a^2 + 2ab} - \sqrt{r^2 - 2br}$;

$$\therefore\ r - (a + \sqrt{a^2 + 2ab}) = -\sqrt{r^2 - 2br}.$$

On squaring both sides, r^2 cancels, and

$$2a^2 + 2ab + 2a\sqrt{a^2 + 2ab} - 2r(a + \sqrt{a^2 + 2ab}) = -2br.$$

Hence $$r = a\frac{a + b + \sqrt{a^2 + 2ab}}{a - b + \sqrt{a^2 + 2ab}}.$$

CONIC.—If a_1, b_1 be the lengths of CP, CD conjugate semi-diameter of an ellipse, and θ_1, θ_2 be their inclinations to the major axis, then

$$a_1^2 \sin 2\theta_1 + b_1^2 \sin 2\theta_2 = 0$$

With the usual axes and notation, let ϕ denote the eccentric angle of the point P, then $\phi \pm \frac{\pi}{2}$ denotes the eccentric angle of D. The co-ordinates of P are $a\cos\phi$, $b\sin\phi$; and those of D are $\pm a\sin\phi$, $\pm b\cos\phi$. Hence

$$a_1 \sin\theta_1 = a\cos\phi \quad . \quad . \quad . \quad . \quad (1)$$

$$a_1 \cos\theta_1 = b\sin\phi \quad . \quad . \quad . \quad . \quad (2)$$

$$b_1 \sin\theta_2 = \pm a\sin\phi \quad . \quad . \quad . \quad (3)$$

$$b_1 \cos\theta_2 = \pm b\cos\phi \quad . \quad . \quad . \quad (4)$$

Multiply (1) by (2), and (3) by (4), and add the results; then

$$a_1^2 \sin\theta_1 \cos\theta_1 + b_1^2 \sin\theta_2 \cos\theta_2 = 0$$

or $$a_1^2 \sin 2\theta_1 + b_1^2 \sin 2\theta_2 = 0.$$

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TECHNICS CORRESPONDENCE

To the Editor of TECHNICS.

DEAR SIR,—I would like to draw your attention to part of Captain Brown's letter in your September issue.

You will observe that he says: "The Great Pyramid shows clearly that its designer knew very accurately the value of π . . . ." Now the usual points of mathematical interest about the dimensions of the Great Pyramid are: (1) The length of each side of its base is $365\frac{1}{4}$ sacred cubits; (2) the area of each of the triangular faces is equal to the square of the height; (3) the ratio of the perimeter of the base to the vertical height is the same as that of the circumference of a circle to its radius, *i.e.*, 2π. Now it will be seen from the following calculation that the first two of these data determine the third.

For let x = altitude of the triangles which form the faces. Then the area of each face

$$= \frac{365{\cdot}25\,x}{2}.$$

If h = height of the pyramid,

$$\frac{365{\cdot}25\,x}{2} = h^2;$$

$$\therefore h^2 = 182{\cdot}62\,x \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Now by Euclid (1-47)—

$$h^2 + \left(\frac{365{\cdot}25}{2}\right)^2 = x^2;$$

$$\therefore h^2 = x^2 - 33352 \quad . \quad . \quad . \quad . \quad (2)$$

Eliminating h from (1) and (2)—

$$182{\cdot}62\,x = x^2 - 33352 \quad . \quad . \quad . \quad (3)$$

From which $x = 295{\cdot}49$ or $-112{\cdot}87$.

If x is a negative quantity, the value of h becomes imaginary, so we must disregard the second value.

From equation (2)—

$$h^2 = 182{\cdot}62 \times 295{\cdot}49.$$

The perimeter of the base is equal to $4 \times 365{\cdot}25$. Let the ratio of the perimeter of the base to the vertical height h be denoted by K. Then

$$K = \frac{4 \times 365{\cdot}25}{\sqrt{182{\cdot}62 \times 295{\cdot}49}} = 6{\cdot}2894.$$

The value of 2π is $6{\cdot}2832$, correct to the fourth place of decimals. Thus it appears that K is very nearly equal to 2π.

Surely it is quite possible that the Pyramid was constructed on the first two data, and that the third was an accidental result? In any case, I consider it far more probable that the value of π, if known to the ancient Egyptians, was found experimentally.

I remain,

Yours faithfully,

E. DE BARRY BARNETT.

Malvern, Sept. 24th, 1904.

To the Editor of TECHNICS.

DEAR SIR,—Your solution* of

$$\int_0^{\pi} \frac{x \tan x}{\sec x + \tan x}\,dx$$

is correct; it is your correspondent who is at fault, both in "page" and example.

The example is from Edwards's Differential and Integral Calculus, p. 132, and reads

$$\int_0^{\pi} \frac{x \tan x}{\sec x + \cos x}\,dx. \quad (Poisson.)$$

Multiplying by cos x, we obtain

$$I = \int_0^{\pi} \frac{x \sin x}{1 + \cos^2 x}\,dx.$$

Integrating by parts, we obtain

$$I = \Big[- x \cdot \tan^{-1}(\cos x) \Big]_0^{\pi} + \int_0^{\pi} \tan^{-1}(\cos x)\,dx$$

$$= \frac{\pi^2}{4} + I'.$$

$$I' = \int_0^{\pi} \tan^{-1} \cos(\pi - y)\,dy.$$

Substituting $y = \pi - x_1$, we obtain

$$I' - \int_0^{\pi} \tan^{-1}(\cos y)\,dy = - I'$$

$$\therefore I' = 0;$$

$$\therefore I = \frac{\pi^2}{4}.$$

That I' is zero can also readily be seen from a diagram. The curve is symmetrical about the point $y = 0$, $x = \frac{\pi}{2}$; $\therefore$ area = zero.

Yours faithfully,

J. M. CHILD.

Technical College, Derby,
October 12th, 1904.

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* See TECHNICS, No. 10, October, 1904, p. 412.

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded to the "Technics" Prizeman.

£25 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 101 competitions have been given in the preceding ten numbers of TECHNICS.

The present number contains particulars of 7 competitions, for which money prizes amounting, in the aggregate, to £25 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£25 IN PRIZES.

General Rules.

Competitors are requested to note the following rules :—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must be executed in black ink, and not shaded in wash, or coloured.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, TECHNICS, 12, Burleigh Street, Strand, W.C., and must reach these offices not later than December 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

ELECTRIC TRACTION.

£1 10s., £1, and 10s. for the three best answers in order of merit.

Draw a complete set of Speed-Time, Distance-Time, and Speed-Distance curves (similar to those given in Fig. 16, p. 428) for a one-mile run, average speed forty miles per hour, acceleration at the rate of 1·0, 1·4, 1·8, and 2·2 miles per hour per second. Assume braking retardation to be equal to acceleration.

MECHANICAL ENGINEERING.

£3 for the best answer.

Describe the latest developments in valves for steam engines ; discuss the purpose for which they have been specially designed, and illustrate your answers with working drawings.

ELECTRIC HEATING.

£3 for the best answer.

Describe any industry or industries with which you are acquainted, in which heating by electricity could be advantageously used : give details.

COLOUR PHOTOGRAPHY.

£1 10s., £1, and 10s. for the three best answers in order of merit.

Explain, as clearly as you can, why it is that a mixture of *blue* and *yellow* paints produces a *green* paint, while a mixture of *red* and *green* light rays produces a colour sensation of *yellow*.

TEXTILE INDUSTRIES.

£2 and £1 for the two best answers in order of merit.

Discuss the difficulties of winding yarns from ball warps on to warpers' bobbins, giving special prominence to your own experience.

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ELECTRO-MAGNETIC THEORY.

£5 for the best set of answers.

1. Prove from first principles that the tubes of force stretching between the plates of a plane condenser are (1) straight; (2) normal to the plates; and (3) cylindrical in shape.

2. How will the mutual attraction of the charged plates of a plane air condenser vary with the distance between the plates (1) when this distance is small; and (2) when the distance is considerable? Deduce your results from the properties of the tubes of force.

3. State in your own words the grounds on which the conclusion is formed that electric tubes of force, when moving perpendicular to their lengths, possess inertia.

4. Suppose that the discharge circuit of a condenser consists of two straight wires placed parallel to each other and joined at the remote ends, but that one of these wires is cut at a certain point, its cut ends being joined to the extremities of a circular turn of wire; how will the tubes of force distribute themselves during the discharge?

THEORY OF STRUCTURAL DESIGN.

£3 and £2 for the two best sets of answers in order of merit.

1. What are the advantages and disadvantages of Gordon's pillar formulæ?

2. Explain fully why a sliding factor of safety is used for pillar formulæ.

3. After re-reading the three last issues, explain fully in your own words the difference between the crippling load per square inch on a pillar and the crippling stress per square inch; also draw a distinction between the safe stress per square inch and the safe load per square inch.

4. What do you consider constitutes good practice in the width and thickness of base plates for square, built-up, mild steel stanchions of the following diameters or transverse dimensions: 1 in., 1½ in., 2 ins., 2½ ins., 3 ins.

RESULTS OF AUGUST COMPETITIONS.

THEORETICAL MECHANICS.

PRIZE, £3.—Divided between two competitors: Charles Ernest Savage, 133, Station Street, Loughborough, Leicestershire; H. A. Stewart, Sunnyside, York Road, Southend-on-Sea.

SPECIAL HONOURABLE MENTION:—James S. Ormiston; Keir Bonallo; M. W. Brayshay; Hugh Sumner; S. Irwin Crookes.

HONOURABLE MENTION:—Samuel Lees; A. Richards; Jas. Mitchell; F. W. F. Moir; G. Lees.

RADIUM.

PRIZE, £3.—Gordon S. Hardy, St. John's College, Cambridge.

SPECIAL HONOURABLE MENTION:—Samuel Lees; Edgar P. Hedley; J. Augustus Robertson; H. H. Francis Hyndman; S. Irwin Crookes; Isidore Henry Harris; Harry Hutchinson.

HONOURABLE MENTION:—G. Lees; Harold Slicer; R. M. Sheppard.

PRACTICAL MECHANICS.

PRIZE, £3.—Geo. A. Pover, Cavendish Villa, 53, Hencroft Street, Slough.

SPECIAL HONOURABLE MENTION:—H. G. Lester; Jesse Haigh Baxter; Frederic P. Marsden.

HONOURABLE MENTION:—W. C. Taylor.

WEAVING.

PRIZE, £3.—Harry Percy Curtis, 5, Bickley Street, Moss Side, Manchester.

SPECIAL HONOURABLE MENTION:—J. E. Tytler.

HONOURABLE MENTION:—Frederic Stones.

ELECTRICAL ENGINEERING.

PRIZE, £3.—P. E. Banting, Mona House, Manor Road, Rugby.

SPECIAL HONOURABLE MENTION:—H. A. Stewart; M. Finn; Charles Ernest Savage; S. Irwin Crookes; William J. Williams; William Gillespie, R. F. Chaffer; H. H. Francis Hyndman; R. E. C. Ihlee.

HONOURABLE MENTION:—R. M. Sheppard; F. B. Magee; Stanley A. Okell; Cresswell J. Vickery; Frank Shaw; Arthur Gadd; J. A. Lovell.

ELECTRIC WAVES.

PRIZE, £5.—Divided between two competitors: Walter Brown, 75, Prince Edward Street, Crosshill, Glasgow; Robert H. Buckie, c/o The British Uralite Co., Ltd., Higham, near Rochester, Kent.

SPECIAL HONOURABLE MENTION:—R. C. Clinker; John F. Punch; Hilton Grace; Gordon S. Hardy; F. Shaw; H. W. Kefford; Samuel Lees; Gordon Stewart; J. M. Chippendale.

HONOURABLE MENTION:—S. Irwin Crookes; Thomas Royds; A. Richards; R. M. Sheppard; Sydney Read; Walter Saville; H. H. Francis Hyndman.

THEORY OF STRUCTURAL DESIGN.

PRIZE, £5.—Samuel Lees, 1, Trafalgar Street, Broughton, Manchester.

SPECIAL HONOURABLE MENTION:—Arthur Gadd.

HONOURABLE MENTION:—D. E. Synan; Archibald Reid; Hugh Sumner; Harold Slicer; K. Bonallo.

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PERSONAL ITEMS.

OUR attention has been drawn to a clerical error in Mr. Scott Taggart's article on the "Arrangement of Machinery in a Modern Copper Mill," (TECHNICS, No. 10, Oct. 1904, p. 396). The productions of the Hopper Bale Breaker should be, for Egyptian cotton 1,500 lbs. per hour, instead of 15,000 lbs. per hour as printed; and for American Cotton, 4,000 lbs. per hour, instead of 40,000 lbs. per hour as printed.

THE Manufacturers' Section of the London Chamber of Commerce has recently forwarded the following resolution to the President of the Board of Education :—"That in order to retain our industrial position and to introduce into this country such further industries as may be profitably developed, this Section is of opinion that it is absolutely necessary to raise the standard and, if possible, cheapen the cost of technical and higher technical education, and that representations be made to the Board of Education in this sense." It was also pointed out that there is hardly an industry that would not benefit by the more general employment of specially qualified scientific assistants; at present, most of the qualified assistants available are natives of the Continent, or at least have received a continental training. In reply to this resolution Mr. Morant, on the part of the Marquis of Londonderry (President of the Board of Education), expressed his sympathy with the aims of the Chamber of Commerce, and explained that, in co-operation with the London Education authorities, the Board of Education hopes to provide an extension of special training of an advanced kind. It was further pointed out that the salaries offered by English firms to qualified scientific assistants are generally too small to tempt English students. The need of an improved secondary education in England was also dwelt on.

WE are requested to announce that the London offices of Messrs. John Davis & Son (Derby), Ltd., have been removed from 26, Victoria Street, Westminster, to Camomile Street Chambers, London, E.C.

THE opening meeting of the Glasgow Technical College Scientific Society was held on Saturday, Oct. 15, when the President, R. D. Munro, Esq., M.I.C.E., delivered the presidential address.

WE are pleased to note that out of the whole number of senior students prepared for the City and Guilds of London examination in Photography, by Mr. Edgar Senior, only one failed. Four students passed in the Honours division—two first and two second. Mr. Benjamin Pearson gained the First Class Honours Silver Medal.

THE Lofthouse Colliery Company, near Wakefield, Yorkshire, have placed an order with Messrs. Graham, Morton & Co., Ltd., Leeds, for the supply and erection of a new Pit Head Frame, consisting of a lattice-braced structure, 55 feet high, with splayed legs, struts and girders, cage kep gear frame, and guide angles, and supports for cage safety detaching cylinders, &c.

MR. CLAYTON BEADLE'S article on the "Fibrous Constituents of Paper" reached us too late for insertion in this issue. Mr. Beadle is carrying out special researches in connection with these articles; we understand that the labour entailed in these researches is answerable for the late arrival of the instalment that would otherwise have appeared in this number of TECHNICS.

A METHOD of equalising the load in generating stations, which is coming rapidly to the front, is that known as the "Thermal Storage System." The Halpin system was described by Mr. C. N. Russell, in a paper on "Refuse Destruction and Heat Utilisation," read at the joint meeting of the Institution of Mechanical Engineers and the American Society of Engineers, at Chicago, on June 1st. At times of low load, part of the steam generated is led into closed water tanks, where it parts with its heat, thereby raising the temperature of the water to a value corresponding to a steam pressure of 200 lbs. per square inch. At times of high load this heated storage water is used to feed the boilers, and also, partly, to evaporate and produce steam at from 200 lbs. to 120 lbs. per square inch pressure. This system appears to have much to recommend it, and will probably be found to compare favourably with the use of electrical storage batteries.

THE Publication Committee of the Chemical Society has decided to spell the word "radical" as "radicle." One hundred and seventy-nine Fellows of the Society have signified their disapproval of this innovation. They point out that: (1) The new word *radicle* does not convey the sense which the authors of the word *radical* intended, or that which is still attached to it in chemistry. (2) The word *radical*, though derived from the French, can be defended on purely philological grounds. (3) The original word should be retained out of regard for its historical origin, for a reason similar to that admitted in our retention of the name "oxygen," although the original meaning of this word has been modified. (4) The original word *radical* is still retained on the Continent and in America, and it is only in this country that the change has been made.

AT the recent meeting of the British Association at Cambridge, Professor Dixon discussed the specific heats of gases at high temperatures, with special reference to the gases burnt in internal combustion engines. He stated that it is impossible to completely burn carbonic oxide (CO) at a high temperature. As a general result, it appears that the specific heat of carbonic oxide increases with the temperature up to a certain point, where dissociation begins.

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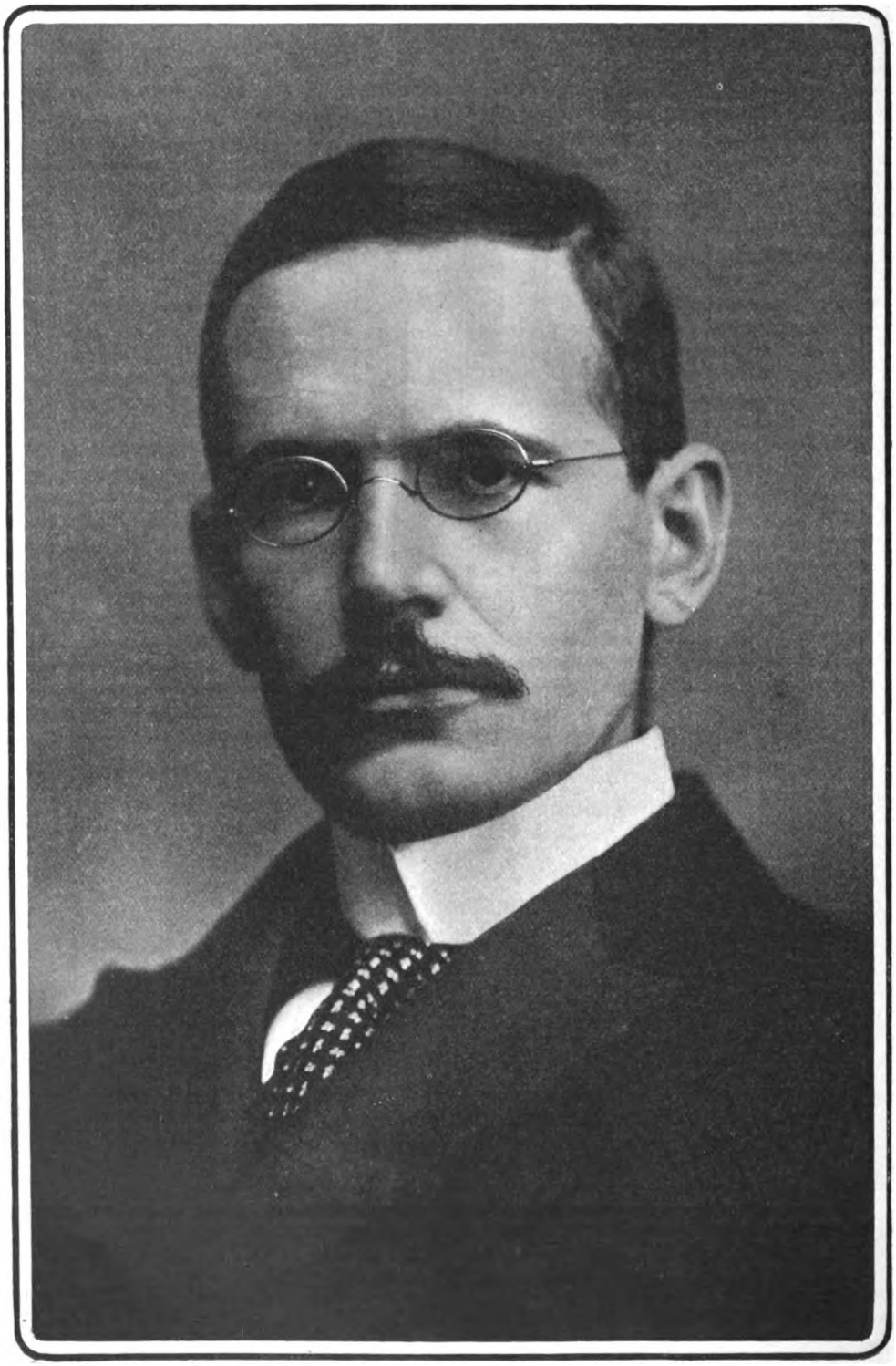

MORRIS W. TRAVERS, D.Sc., F.R.S.

Photo. by Geo. Newnes, Ltd.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. II. DECEMBER, 1904. NO. 12.

PROGRESS OF SCIENCE AND TECHNOLOGY.

Quartz Lenses and Prisms for Spectroscopic Work

THE use of quartz lenses for spectacles is mainly of advantage because of the greater hardness of the rock-crystal as compared with glass. In recent years, however, quartz lenses and prisms have been widely used, especially for spectroscopic work, on account of their transparency to ultra-violet light. It is thus possible to photograph an emission or absorption spectrum over the whole range within which a photographic plate is sensitive. This method has been used with marked success by Professor Hartley, and by Professor Dobbie and Mr. Lauder in their striking papers on the absorption spectra of the alkaloids, which have recently been published in the *Journal of the Chemical Society*. The source of light was a spark discharge between poles formed of an alloy of tin, lead and cadmium, a combination of metals which gives a brilliant series of lines distributed over the whole range of the spectrum. In order to avoid double refraction, it is necessary that the light should travel through the crystal along the optic axis, and only narrow-angle lenses can therefore be employed.

Lenses of Fused Quartz

AT the Paris Exhibition, the firm of C. Zeiss were able to show three optically homogeneous plates of fused quartz about 10 mm. thick and 40 mm. in diameter, suitable for grinding down into lenses. To prepare plates of this kind, somewhat special treatment of the natural quartz is necessary, partly because there is a sudden change in the expansion at 570° C. which has a great tendency to crack the crystal, and partly because the half-fused product is so viscous that it is exceedingly difficult to obliterate air-bubbles or cracks if these are once present in the mass. The method adopted has recently been described by Herschkowitsch in the *Zeitschrift für Physikalische Chemie*. The natural crystals are heated to 500° in a muffle furnace, and are then plunged suddenly into a white-hot electrical furnace. The crystalline structure of the quartz is thus destroyed, although the temperature is not sufficient to liquefy the mass completely. The specific gravity of the amorphous quartz is 2·204 as compared with 2·651 for the natural crystal, and its refractive index for sodium light is 1·4585.

Radium and Helium

THE occurrence of helium in the gases liberated from radium salts, as observed by Ramsay and Soddy, and by Dewar and Curie, has already been referred to in these columns. Similar experiments have recently been carried out by Himstedt and Meyer at Freiburg. In the first experiment, the tube, in which the emanation from fifty mg. of radium bromide had been collected, was examined with negative results during a period of no less than three months; but at the end of five months it showed the characteristic lines of the helium spectrum. In a second series of experiments, in which 25 mg. of the sulphate were used, the helium lines were seen after three weeks, but were rendered much more distinct when a second gas, which gave a band spectrum, was removed by condensing in liquid air. The spectrum of this gas could not, however, be measured, and it was not possible to decide whether the gas was the emanation or merely carbon monoxide.

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A Problem connected with the Flow of Rivers

THERE is a very general belief that a boat can float down a smoothly flowing river at a speed exceeding that of the flowing water. In support of this belief, an argument somewhat like the following is often adduced :—

The river necessarily flows from a higher to a lower level, and therefore its surface is

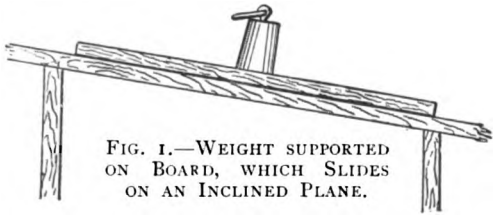

FIG. 1.—WEIGHT SUPPORTED ON BOARD, WHICH SLIDES ON AN INCLINED PLANE.

inclined in the direction of flow. If we suppose the boat to merely slide down the inclined plane formed by the surface of the river (the water being stationary), then it would acquire a definite velocity dependent on the friction between the boat and the plane. If, now, the water is supposed to move in the same direction as the boat, the relative motion between the two would be less, and therefore the friction would be less and the final velocity of the boat greater. Fig. 1 represents a weight supported on a board which itself slides down an inclined plane. If there is no friction between the weight and the board, or between the board and the plane, then the weight and the board will move together, the acceleration of one being exactly equal to that of the other; but if there is friction

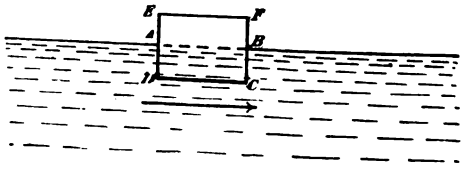

FIG. 2.—TO EXPLAIN THE EFFECT OF THE SURROUNDING WATER ON A BOX FLOATING DOWN A RIVER.

between the board and the plane, then the weight might move more quickly than the board. This argument appears very plausible, but it does not take into account the essential properties of the flow of water.

A section along the length of the river is represented in Fig. 2. If the cross-sectional area of the river is everywhere uniform, it follows that the velocity of flow of the river will be the same at all points in its course; for if the flow through a given cross-section in a given time is not equal to the flow through any other cross-section in the same time, there would either be an accumulation or a progressive decrease of the water between these sections. Thus, if we take a rectangular parallelepiped of water represented in longitudinal sections by A B C D, Fig. 2, the water contained within this parallelepiped must move with a uniform velocity, and therefore must be acted upon by no resultant force. It is easily seen that the resultant force due to the action of the surrounding water on the parallelepiped will just serve to neutralise the downward pull of gravity. If we now replace the water within the parallelepiped A B C D by a solid with its upper surface flush with the surface of the river, the action of the surrounding water on this will be exactly the same as on the water originally contained in the parallelepiped. Therefore the solid will move exactly as the water did. If the solid floats only partly immersed, as at E F C D, its mass must still be exactly equal to the mass of water displaced, and therefore the action of the surrounding water will just neutralise the downward pull of gravity, and the body will still move at the same rate as the water. If by any chance it was set in motion with a greater velocity than the water, this velocity could not be maintained; the velocity of the body would quickly fall to that of the surrounding water.

A Gas-propelled Boat

A NEW development of the internal combustion motor for boat propulsion has recently been undergoing trials at Hamburg. This is a gas engine and generator complete, and is to the design of Herr Emil Capitaine. The fuel used is anthracite coal and the gas generator is of the suction type. The object of the scheme is to secure greater economy, and trials have proved that it effects considerable economy over the steam engine and boiler, while the total weight of machinery is only slightly heavier. The weight necessary for horse-power is, of course, far in excess of what is required for an internal combustion oil engine; but the economy in cost of fuel is so great that in many cases, no doubt, weight can be overlooked. Further trials of this interesting vessel will undoubtedly be looked for with interest.

TWIN solid rubber-tyred wheels appear to have gone a long way towards the solution of the tyre problem for heavy motor omni-

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buses. This system of tyring was introduced a short time ago by the Sirdar Rubber Company, and is now generally accepted as the only satisfactory method for the back wheels of heavy motor vehicles running at moderately high speeds. It consists substantially of two solid rubber tyres, placed side by side on one felloe; these are more durable and flexible than one large tyre. The limit of height above the rim for solid rubber tyres is soon reached, owing to their liability to roll sideways and pull out of the rim, and wide tyres are uneconomical, owing to their lack of resilience and liability to crack, so that it was a difficult matter to know how to construct

Twin Tyres

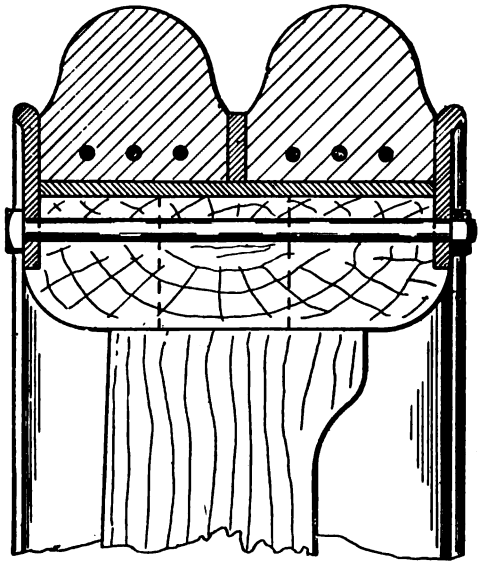

FIG. 3.—TWIN TYRES FOR HEAVY MOTOR OMNIBUSES.

tyres to economically carry the weight necessitated by large omnibuses for public service. Careful experiments show that indiarubber is almost incompressible; consequently if it is compressed in one direction it must expand nearly equally in another. One can readily see that the rubber in a twin tyre, being divided into two independent parts, has four surfaces from which it can expand laterally, so that for the same amount of surface exposed to the load, a twin tyre is more flexible than a single one; also, as the average deformation is less for a given load, it is less liable to crack, and is consequently more durable. In addition to this, practice shows that a twin tyre is less liable to side-slip than a single one, and certain types have the additional advantage of being still temporarily serviceable if one tyre should pull out. Twin tyres are not suitable for front wheels, owing to their making the steering difficult; but they are not generally so necessary here, as the load is usually much less on the front than on the back axle.

The Composition of Tramway Rails

THE chemical composition of a steel tramway rail is a matter of the greatest importance, owing to the influence that it has upon the life and general efficiency of the track. In comparison with the methods of a few years back, modern practice shows a tendency to increased hardness of rails: the heavier rolling stock and higher speeds employed at the present day require a rail of great durability, and one that is capable of withstanding the pounding action of the car wheels at joints and crossings. Also, the very frequent and sudden stoppages necessary in tramway work must be taken into account, since an abrupt halt will often cause the wheels to skid, and when the rails are "greasy," starting is usually accompanied by much slipping and spinning of the wheels; both causes have a very serious effect on the life of the rails, and call for some considerable hardness. The percentage of carbon (to which hardness is due) varies with the weight of the rail per yard, and may be 0·43 per cent. for a 60-lb. rail, and 0·5 per cent. for one of 100-lb.; intermediate weights varying proportionately. Higher degrees than this, amounting to one per cent., are used in America, but with the undesirable result of extreme brittleness.

Manganese is added to produce increased ductility, in order to facilitate rolling; it should not be present in greater quantities than 0·85 per cent. and 0·95 per cent. for 60 and 100-lb. rails respectively: it considerably increases the electrical resistance, and what is more important, causes crystallisation and consequent weakness when in excess. Phosphorus is undesirable on account of the brittleness that it produces, and should never exceed 0·1 per cent. in any weight of rail: the amount usually present in English rails is 0·06 per cent., and the use of higher amounts is almost entirely confined to American methods, which result in the production of a cheaper rail, but one also of greatly reduced durability.

Sulphur is objectionable, as it tends to the production of seams; and as it fulfils no useful purpose, it should be kept as low as possible, never exceeding the percentage allowed for phosphorus in best practice.

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The usual limit for silicon is 0·2 per cent. in all weights of rail. This element is not considered objectionable, since it promotes a fine crystalline structure, and produces a very dense metal; it, however, adds largely to the electrical resistance.

Copper, as an impurity, does no harm; but in conjunction with sulphur to the amount of about 0·1 per cent., it produces cracks during the rolling process and other troubles in manufacture.

The question of the permissible content of carbon, and brittleness, must be considered in conjunction with the manner in which the track is laid. If the track is of solid construction, and not at all liable to give, hardness may be safely carried to an extent that would certainly lead to fracture in badly bedded track. In view of this, it is curious that in America, where railroad construction is carried out in a much more flimsy style than is compatible with British ideas of good work, harder rails are used than in this country; breakages are of comparatively frequent occurrence, but there can be little doubt that more substantial construction would reduce them considerably, so that the gradual introduction of harder rails upon this side of the water may be looked upon as a step in the right direction.

Modern Water Gauges for Steam Boilers

THE important part played by water gauges in preventing accidents to steam boilers has been fully recognised in recent times, and much thought and ingenuity have been devoted to perfecting these useful contrivances. The points in which modern gauges differ from those used in past times are:—(1) The provision of means by which the position of the water surface is rendered as distinct as possible. (2) The provision of automatically operated valves which prevent loss of steam or water if the gauge tube breaks. (3) The attachment of the gauge tube is effected in such a manner that no undue mechanical strain is put upon it, thus avoiding risk of fracture.

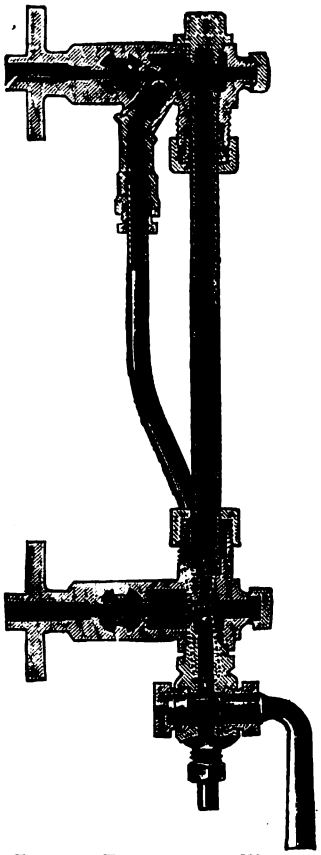

FIG. 4.—THE PARKER WATER GAUGE.

The Parker Water Gauge

FIG. 4 represents a section of the Parker Water Gauge, made by Bell's Asbestos Co., Ltd., of 59½, Southwark Street, London, S. E. The straight cylindrical gauge tube is seen to the right of the illustration; the outlet tube at the bottom of the gauge is closed by a cock, while the pressure of the steam also usually closes the ball valve just above this. The upper extremity of the gauge tube is connected, by means of a metallic tube, with the space between the ball valve and the cock just mentioned: on opening this cock, the ball valve above it prevents the water from issuing directly; but the pressure of the water forces it in a rapid stream up the gauge tube, past the ball at the top of the side tube, which does not entirely bar its progress, down the side tube, and so out through the lower cock. By this means the gauge tube can be readily and efficiently cleaned. In case the gauge tube bursts, the rush of steam over the ball shown at the top of the gauge causes this ball to rise, according to the well-known hydrodynamical principle, "where the velocity is greatest the pressure is least"; the ball then nearly stops the issue of the steam, but a small jet is allowed to escape, in order to attract the attention of the person in charge. The pressure of the steam, acting downwards through the metallic side tube, now causes the lower ball to rise and so obstruct the passage of the water into the broken gauge glass. It is easily seen that the valves are thoroughly washed by water during each blow through, so that the possibility of their becoming clogged by deposits from the water is obviated. All cocks are asbestos packed.

Hulburd's Gauge

THE necessity for providing two independent water-gauges on steam boilers has hitherto been met by mounting two entirely separate fittings of similar design on the boiler front. This method involves a double set of holes in the boiler-plate, and the two gauges require more room than can well be spared, particularly in

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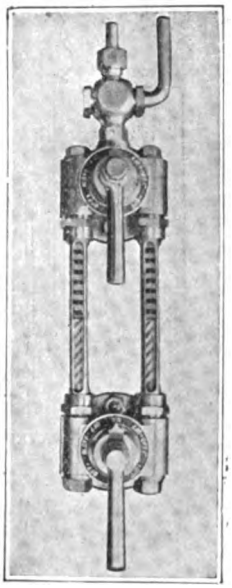

FIG. 5.—HULBURD'S TWIN GAUGE.

the case of locomotives, where a large number of fittings have to be provided in a very limited space. Fig. 5, which represents Hulburd's Patent Duplex Water Gauge, shows a form of gauge which avoids these drawbacks by carrying the two water-gauge columns on the same set of flanges, and has the further advantage that both glasses are controlled by one pair of handles, so arranged that either glass may be shut off wholly or partially without interfering with the action of the other. Dials are provided behind each handle, to indicate the position to which it must be turned to shut or open either or both glasses, or to connect them both to atmosphere for blowing out. Each column has a separate entry to the boiler in both top and bottom fittings; a hole drilled through the plug allows a wire to be inserted for the purpose of cleaning out either entry. The top and bottom arms are also provided with small mushroom valves, those on the lower arm completely closing the passages automatically in case of a glass bursting. The valves in the upper arm are drilled with a small hole, which, in case of a cracked glass, reduces the escaping steam to a harmless but visible jet. These valves are now made to come off with the top cap, and cannot be accidentally omitted when replacing the cap. The plug-cocks are asbestos-packed, but not tapered, so that they have no liability to jam in their seatings. The gauge glasses are contained in brass cartridges, which serve as guards; they are packed in the cartridges by rubber washers, and one or more of the complete cartridges is kept in readiness near the boiler. In case of a glass bursting, the gland-nuts round the existing cartridge are slightly slackened, the upper cap with its mushroom valve attached is removed, the old cartridge withdrawn, and the new one inserted from the top. The cap is then replaced, and the gland-nuts tightened. No vertical pressure is exerted on the glass tube by the packing, thus removing a cause which often results in the immediate breakage of a new glass. The insertion of a new glass in the cartridge is done at leisure, and any undue or uneven pressure caused by careless tightening of the gland-nuts in the hurry of replacement is shielded from the glass itself by the strong metal casing. Fig. 5 shows the gauges fitted with a device for showing the water-level at a glance. The diagonal stripes below the water-level are magnified and distorted by refraction, through the cylindrical column of water (Fig. 7), making a marked distinction between a full and empty glass. The method of having enamelled stripes on the interior of the guard has been superseded by merely cutting diagonal slots in the back of the guard (Fig. 6), through which the black boiler-plate is seen in strong relief to the white remainder of the guard. The gauges and protectors are manufactured by the Hulburd Engineering Company, 150, Leadenhall Street, E.C.

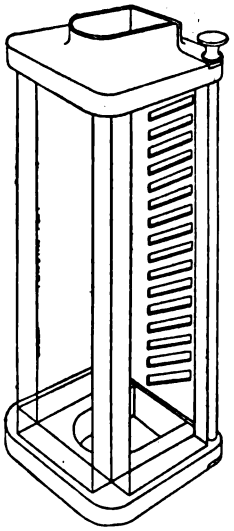

FIG. 6.—GUARD FOR HULBURD'S GAUGE.

SKETCH SHEWING EFFECT OF WATER IN TUBE ON APPEARANCE OF INDICATOR

FIG. 7.

The Stoker's Protector

IN order to protect the person whose business it is to attend to the indications of the water-gauge, it is customary to provide this with a guard-tube, which prevents the projection of steam, boiling water, or glass into the face of the attendant. Fig. 8 represents Bailey's Patent Gauge-tube Protector; this has the merit of being very easily applied to any gauge-glass of ordinary pattern, and no thumb-screws or set-screws are required to fix it. The upper metallic continuation of the protector can be screwed out or in, so as to adapt it to gauge-tubes of different lengths.

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FIG. 8A.

A number of sizes of this protector are made, and it is easy to choose one of these suitable for adjustment to the length required. Fig. 8A shows the same type of protector made with a tube containing a network of wire embedded in its substance, thus rendering breakage of the tube next to impossible.

Low-water Alarm

FIG. 9 represents the Ashcroft "Low-water Alarm," made by W. H. Bailey & Company, Limited, Albion Works, Salford, Manchester. It consists of a metal tube connected to the boiler by a stop valve, which can be secured by a padlock when open, to prevent its being tampered with. At the upper extremity of this tube is an air chamber, in the neck of which is fitted a ½-inch fusible disc, which closes the stem of a steam whistle. When water is in the tube, its temperature cannot rise high enough to melt the fusible disc (the melting-point of the latter being 212° F.), since heat can reach this water only by conduction; but when the level of the water in the boiler falls below the lower end of the tube, steam enters this, melts the fusible disc, and blows the whistle. The sounding of the whistle can only be stopped by the person entrusted with the key of the padlock attached to the stop-valve; when this valve has been closed, the alarm may be unscrewed without emptying the boiler, and a fresh fusible disc can be inserted; the alarm can then be readjusted. Thus accident or injury is prevented, and neglect is detected by the responsible person in possession of the key to the padlock.

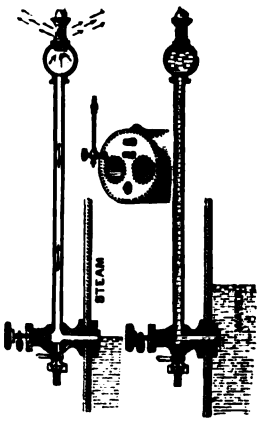

FIG. 9.—LOW-WATER ALARM.

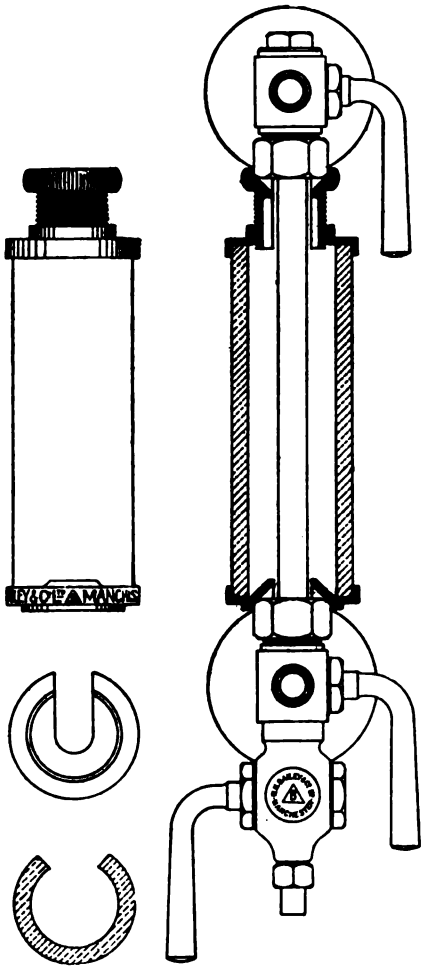

FIG. 8.—STOKER'S PROTECTOR.

Crosby Improved Steam Pressure Gauge

THE most trustworthy steam pressure gauges utilise the property of the Bourdon tube, which tends to uncoil when under internal pressure. If a piece of thin-walled indiarubber tubing is coiled into an arc of a circle, it will be found that the surface perpendicular to the plane of bending becomes flattened, so that the section of the tube becomes elliptical, the major axis of the elliptic section being parallel to the axis about which the tube is coiled. If one end of the tube is now closed, and air is blown into the other end, the tube tends to straighten out. The Bourdon tube consists of a metal tube of elliptical section, bent into an arc of a circle, and closed at one end; the open end is connected to the space whose pressure it is required to measure, and the pressure is indicated by the extent to which the tube uncoils. The chief disadvantage is that, in order to obtain a tube which will uncoil to a sufficient extent under a moderate pressure, the walls of the tube must be thin,

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and this entails the risk of the tube bursting. The Crosby Steam Gauge and Valve Company, of 147, Queen Victoria Street, London, E.C., has succeeded in making a very sensitive pressure gauge, while using a Bourdon tube about twice as strong as those usually employed. This result has been obtained by using two Bourdon tubes, the closed end of one forming a fulcrum for a lever actuated by the closed end of the other tube (Fig. 10); the uncoiling of either tube thus reinforces the other in moving the lever, and so actuating the mechanism which rotates a pointer by which the pressure is indicated. This gauge is specially suitable for high pressures, and is at the same time as sensitive as the ordinary Bourdon gauges. There is no vibration of the pointer, and the tubes may be drained completely to prevent freezing. The tubes are connected at their ends with their respective attachments by means of screw threads, no solder being employed; this is a marked improvement on the ordinary method of using soldered joints, as the temperature of high-pressure steam is sufficient to soften or even melt the solder, thus leading to the destruction of the gauge.

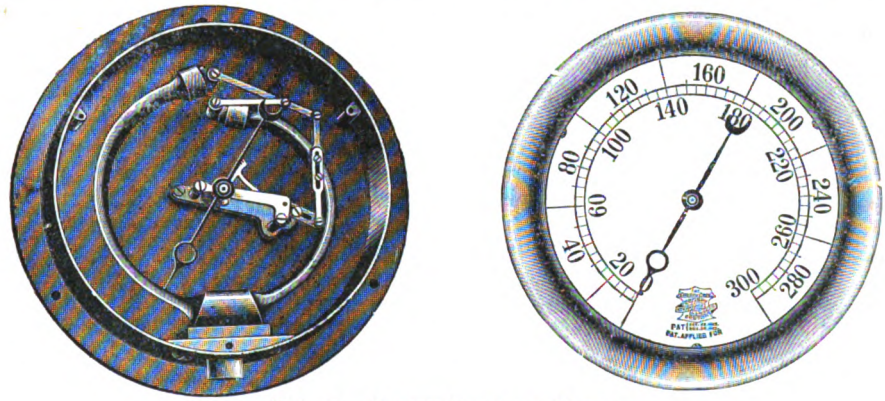

FIG. 10.—CROSBY PRESSURE GAUGE.

AT the present time, much importance attaches to the results of physical tests of paper. Fig. 11 represents the "Dandy Rolls" paper-testing machine, made by Messrs. T. J. Marshall & Company, Campbell Works, Stoke Newington, London, N.

The strip of paper to be tested is fixed at its ends in the clamps A, A. When the screw B is turned in a right-handed direction, the paper is subjected to tension in the direction of its length; the clamped end to the left tends to move forward, but is prevented from doing so by a stop attached to it, which presses against the vertical spring C. This spring moves the horizontal rod D and the lever E, and so turns a geared segment which rotates a pointer. Thus the rotation of the pointer depends on the amount by which the spring C is bent, and therefore serves to measure the pull to which the paper is subjected. The spiral spring G presses on the rod D, and causes this to remain in the position to which it has been forced during the test. A scale at the right-hand end A of the machine measures the elongation of the paper strip. We are informed by Mr. Clayton Beadle that the tests on paper described in this and previous numbers of TECHNICS were carried out by the aid of the "Dandy Rolls" paper-testing machine.

Paper-Testing Machine

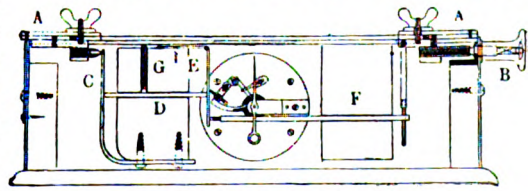

FIG. 11.—"DANDY ROLLS" PAPER-TESTING MACHINE.

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THE DETERMINATION OF RELATIVE ATOMIC MASSES.

By MORRIS W. TRAVERS, D.Sc., F.R.S., Professor of Chemistry at University College, Bristol.

THE conception of atoms, as a means of picturing to ourselves the changes which take place during chemical processes, arose as a natural consequence of the discovery of the laws relating to the proportions by mass or by volume in which chemical substances enter into combination. As a working hypothesis, there can be no doubt that the atomic theory has been of very great use to chemists, though there exists a school, headed by Professor Ostwald of Leipzig, which holds the opposite view so strongly that it considers the terms 'atom' and 'molecule' dangerous and misleading. Some go so far as to state that the use of mental pictures and mechanical similes has a cramping influence, and has tended more to the hindrance than to the advancement of scientific thought. It is a sufficient answer to point to the use which has been made of such methods by scientists like Faraday and Clerk Maxwell.

The determination of the atomic mass of any element usually involves two distinct processes. It is first of all necessary to determine its equivalent—the weight of it which replaces or combines with eight parts by weight of oxygen, or roughly, one part by weight of hydrogen. As will be shown later, the oxygen standard is more usually employed than the hydrogen standard; for though the combining ratio of oxygen and hydrogen is now known, with a fair degree of accuracy, to be as 8 to 1·008, experimental results usually lead more directly to the determination of the ratio $\frac{\text{weight of element}}{\text{weight of oxygen}}$, and there is no advantage in referring them to a standard which may one day call for further revision. It need not be pointed out that the only questions that we have to consider when dealing with equivalents relate to the purity of the substances used, the completeness of the reactions employed, and the accuracy of the methods of manipulation and measurement.

When the value of the equivalent is obtained it is necessary to determine what multiple of it we can take as the atomic mass. The train of reasoning which has led to the acceptance of the current values of the atomic masses will be considered separately.

It is essential to the correct determination of the equivalent of an element, that only perfectly pure substances are employed in the reactions involved. This can only be ensured by obtaining each substance from several different sources, proving that different samples of it have several properties which are quantitatively identical, and that 'fractionation' by chemical or physical processes does not produce any further change in them.

It is preferable to employ solid substances, which form crystalline masses free from water. A substance like silver nitrate is highly suitable for such experiments, though Stas found that the pure salt always underwent a loss of weight when it was fused. In drying crystalline salts containing water of crystallisation, there may be a slight tendency towards slow but steady loss of weight through efflorescence, or the crystals may eventually enclose traces of the solution.

In the case of liquids, though the process of distillation may appear to be an efficient method of purifying them, difficulty is often experienced in removing the last traces of volatile substances. Thus, the determination of the equivalents of elements like boron or silicon by the analysis of their liquid haloids may be vitiated by the presence of traces of the halogen acid in solution.

It has been suggested that the abnormality in the atomic mass of tellurium, which is higher than that of iodine, and not lower as the periodic law would lead us to expect, may be due to impurity of an unknown nature. Certainly some doubt may be thrown on the purity of certain derivatives of those obscure elements, which are associated with thorium and cerium in the rare earths.

In selecting a reaction for the determination of an equivalent, there are certain points which it is important to keep in mind. These I will next discuss in order. To take, for example, a reaction between salts in solution: it must be remembered, that though, for the purposes of ordinary quantitative analysis, the reaction between silver nitrate and sodium chloride solution, which may be written

$$AgNO_3 + NaCl = AgCl + NaNO_3,$$

may be supposed to be complete when equivalent quantities of sodium chloride and silver nitrate have been added, an exact study of the process shows that this is not the case. It is found that, with exactly equivalent

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quantities of the salts present, a small quantity of silver remains unprecipitated : this quantity decreases on the addition of a very small excess of either silver nitrate or of the sodium chloride ; but with a slightly greater excess of sodium chloride, re-solution of the precipitated silver chloride takes place, the quantity dissolved increasing with the excess of sodium chloride. Thus the apparent end-point of reaction is difficult to arrive at, and it does not exactly correspond to the presence of equivalent quantities of the two compounds in the solution.

The explanation is to be found in the modern theory of solution. According to the "ionic hypothesis," bodies like sodium chloride and silver nitrate, when dissolved in water, are partly dissociated, each "ion" so formed carrying an opposite electric charge. Thus,

$$NaCl = (\text{in solution})\ \overset{+}{Na} + \overset{-}{Cl}$$

$$AgNO_3 = (\text{in solution})\ \overset{+}{Ag} + \overset{-}{NO_3}.$$

The extent to which each salt is dissociated increases as its solution is made more dilute. At extreme dilution a salt would be completely dissociated. When solutions of the two salts are mixed, since the silver ion and the chlorine ion form an almost insoluble compound, we may write the equation,

$$\overset{+}{Na} + \overset{-}{Cl} + \overset{+}{Ag} + \overset{-}{NO_3} = AgCl + \overset{+}{Na} + \overset{-}{NO_3}.$$

Now, at the moment when equivalent quantities of the two salts have been added to the solution, there will remain in the solution all the sodium ions and all the nitric ions, while the greater part of the silver ions and the chlorine ions will have disappeared in the formation of solid silver chloride ; but since the latter is very slightly soluble in water, a few silver ions and a few chlorine ions will remain. There will be a balance, or condition of equilibrium, between the solid silver chloride and the silver and chlorine ions in solution—a condition similar to that which exists between a liquid and the vapour in contact with it—for the silver chloride is so very slightly soluble in water that the traces of it dissolved may be supposed to be completely dissociated. The addition of more silver nitrate or sodium chloride, that is to say, of more silver ions or of more chlorine ions to the solution, disturbs this condition, which is found to be represented by the expression,

$$\left\{\begin{matrix}\text{No. of } \overset{+}{Ag} \text{ ions in} \\ \text{unit volume}\end{matrix}\right\} \times \left\{\begin{matrix}\text{No. of } \overset{-}{Cl} \text{ ions in} \\ \text{unit volume}\end{matrix}\right\} = \text{a constant},$$

so that on addition of more $\overset{+}{Ag}$ ions or more $\overset{-}{Cl}$ ions silver chloride must pass out of the solution.

This explains why the point at which most silver chloride is precipitated is not that which usually corresponds to the presence of exact equivalents of the two salts. We shall now see why further addition of sodium chloride induces re-solution of the precipitated silver chloride.

It appears that certain ions are capable of forming addition products, or complex ions, the change in the case under discussion being represented by the equation,

$$\overset{+}{Na} + \overset{-}{Cl} + AgCl = \overset{+}{Na} + \overset{-}{AgCl_2}.$$

Obviously the quantity of solid silver chloride which will go into solution forming the complex ion $\overset{-}{AgCl_2}$ will depend upon the concentration of the $\overset{-}{Cl}$ ions, *i.e.*, on the excess of sodium chloride present. The evidence for the existence of such complex ions cannot be fully discussed here : it suffices to state that it can be shown that, when an electric current is passed through a solution such as one of silver nitrate which contains $\overset{+}{Ag}$ ions and $\overset{-}{NO_3}$ ions, these ions move towards the negative and positive poles respectively ; if, however, the silver is present as part of a complex negative ion, it will move towards the positive pole during the passage of the current (p. 534).

Excess of silver nitrate does not induce re-solution of the silver chloride, for it appears that under these conditions neither $\overset{+}{Ag}$ ions nor $\overset{-}{NO_3}$ ions readily form complex ions with silver chloride.

These considerations lead to the conclusion that if we are to employ this reaction to determine the mass relationship between silver nitrate and silver chloride, we can proceed by one method only. We must take a known weight of sodium chloride in solution, add to this a solution containing a known excess of silver nitrate, and, after removing the precipitated silver chloride, estimate the quantity of silver remaining in the solution. This is practically the method employed by Stas in one series of his classical researches on the atomic mass of silver. The theory of the process was not understood at the time.

The same remarks apply to nearly all cases of precipitation from solution. Take as an example the conversion of barium chloride into the sulphate : the mixing of solutions containing exact equivalents of barium chloride and sulphuric acid would result in

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the precipitation of the greater part of the barium as sulphate, but there would remain in solution a small amount of barium and an equivalent amount of (SO_4), such that,

$$(No.\ of\ \overset{++}{Ba}\ ions) \times (No.\ of\ \overset{--}{SO_4}\ ions) = some\ constant.$$

The addition of excess of sulphuric acid would increase the concentration of the $\overset{--}{SO_4}$ ions, so that to maintain the balance the number of $\overset{++}{Ba}$ ions must decrease, with the result that the precipitation of the barium as sulphate would practically be complete.

The majority of the reactions by which equivalents have been determined are carried out in the absence of water, and we have here to consider other influences which may affect the results. Though the apparently ideal method for the determination of the equivalent of an element with regard to oxygen should consist in determining the mass change on oxidation of the element or on decomposing a simple oxide, this method has hardly ever been employed. In the first place, it is difficult to obtain the oxides in a state of sufficient purity; and in the second place, in the case of metals such as copper or lead, the oxide is "soluble" in the metal—for we may doubtless speak of a homogeneous mixture, whether solid or liquid, as a solution—and the hydrogen or other reducing agent employed cannot do its work perfectly, at least in such time as can be given to an experiment. The determinations of the equivalents of carbon and phosphorus (the former by Dumas), by the direct combustion of the elements in oxygen, are almost the only results which this method has yielded.

The various attempts which have been made to determine the mass ratio *(oxygen)/(hydrogen)* in water merit separate discussion. In the earlier experiments the method generally consisted in estimating the loss of weight of copper oxide when hydrogen was passed over it, and weighing the water formed; the weight of the hydrogen appearing as the small difference between two large quantities. This difficulty was first surmounted by Cooke and Richards, in 1887, by actually weighing the hydrogen compressed into a large glass globe: they obtained 1·008 for the equivalent of hydrogen, taking that of oxygen as 8. In the next year Keiser introduced a further improvement. He introduced hydrogen into a tube fitted with a stop-cock, containing spongy palladium, which absorbs the gas to the extent of 0·006 grams of hydrogen per gram of metal. The method has the advantage that the common impurities are not absorbed, and can be removed from the tube by exhaustion; and that the gas can easily be liberated by gently warming the tube.

In 1895, Morley published, in the "Smithsonian Contributions to Science," an account of his researches on the combining proportions of oxygen and hydrogen. Making use of the knowledge acquired by Cooke and Richards, Keiser, and others, and bringing an enormous amount of ingenuity to bear on the work, he obtained some remarkably concordant results. This method consisted in weighing the oxygen in density globes, and the hydrogen after absorption by palladium, and introducing the gases through platinum jets into a sealed glass apparatus in which they were burned. The water formed remained in this apparatus, which was weighed before and after the experiment, and the quantity of oxygen or hydrogen remaining over was determined separately. Morley thus obtained the weights of the oxygen, of the hydrogen, and of the water.

The following are the results of the researches that have been referred to:—

Name of Investigator.	Substances Weighed.	Equivalent of Oxygen, H = 1.
Cooke and Richards, 1887	H and O	7·934
Keiser, 1888	H and H_2O	7·975
Keiser, 1898	H and H_2O	7·934
Morley, 1898	H and H_2O	7·939
Morley, 1898	O and H_2O	7·939

If we take the equivalent of oxygen to be 8, that of hydrogen is 1·008.

It is the uncertainty which inevitably attaches to such experiments, that has led to the adoption of the oxygen basis as a standard for the determination of atomic masses. The list of atomic weights, which is published annually by an international committee first appointed about four years ago, contains the values referred to both standards.

An analogous method is the reduction of halogen derivatives by hydrogen, employed by Stas for the determination of the ratio *(silver halogen derivative)/(halogen)*. The reverse process (the conversion of the element into its chloride) is usually more difficult to carry out, and may in some cases be objected to on the ground that there is a tendency on the part of the halogen to adhere to the compound in excess.

We must next consider the decomposition of a compound by heat. Here we have to

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contend with two sources of error: either the compound may be incompletely decomposed, or may undergo secondary changes; or solid matter may be carried away mechanically by the escaping vapour.

Let us first consider an example, such as the conversion of pure calc spar into calcium oxide- a reaction expressed by the equation

$$CaCO_3 = CaO + CO_2.$$

We must remember that if the substance were heated in a closed vessel, the carbon dioxide would be generated only till a certain pressure, (dependent on the temperature, and called the dissociation pressure) is attained; the reacting substances would then be in equilibrium. If we leave the vessel open, and the temperature is above 800°C., so that the dissociation pressure is greater than the atmospheric pressure, the gas will escape continuously; the same result will be effected by heating to a lower temperature, and passing a current of some inactive gas, such as nitrogen, through the apparatus so as to remove the carbon dioxide as formed. Employing the latter method, and using a platinum vessel, Hinrichsen (1902) has recently redetermined the ratio

$$(CaCO_3)/(CaO).$$

This ratio, and the ratio

$(C) / (O_2) = (12{\cdot}00) / (2 \times 16{\cdot}00)$, found by Dumas, gave the value for the atomic weight of calcium as 40·14 instead of 40·0, which had previously been assumed to be correct. From the analysis of pure calcium chloride, Richards has since obtained the value 40·13. In all such reversible or balanced actions, care must be taken to continuously and completely remove one product of the reaction.

Some other instances of reactions involving the decomposition of a compound by heat are the determination of the ratio

(silver acetate)/silver,

by Maumené, in 1846; of the ratio

(ammonia alum) / (alumina)

determined by Mallet, in 1880; and of

(borax crystals) / (water of crystallisation)

determined by Ramsay and Aston.

It will be observed that, as it is impossible in the majority of cases to determine the ratio *(element) / (oxygen)*, we are obliged to use indirect methods of calculation: a process which is undesirable, for the obvious reason that errors tend to accumulate. The more important direct determinations are the ratio

$$(C) / (O_2) = 12{\cdot}00 / 2 \times 16,$$

first obtained by Dumas, and since fully confirmed; and the combined ratios

$$(AgClO_3) / (AgCl) \text{ and } (AgCl) / (Ag),$$

which give the ratios of the equivalents of silver, chlorine, and oxygen as 107·94:35·45:8. With few exceptions, it is on this basis that our present scheme of atomic masses is built up.

In dealing with the actual experimental methods employed by the various workers on this subject, it is interesting to enquire into such questions as the relationship between the quantities of substances employed and the accuracy of the results arrived at. Berzelius, Dumas, Maumené, and others who, among the earlier workers, are responsible for really accurate work, used comparatively small quantities (not more than 10 grams), and weighed with a degree of accuracy usually not greater than half a milligram. Stas introduced a new principle: hoping to attain a far higher degree of accuracy than those who had preceded him, he sometimes used as much as 400 grams of material, and employed refined methods of weighing. The care with which Stas prepared his material precluded any possibility of contamination by impurity; but a careful study of his results points, in some cases, to the obvious fact that the values of equivalents obtained by some methods vary consistently and regularly with the masses of the particular substances taken for analysis. Thus, if we calculate the equivalent and the atomic mass of nitrogen from the ratios already given, and from the ratio

$$(AgNO_3) / (Ag),$$

we find that the latter approaches 14·00, as the mass of silver nitrate weighed approaches 500 grams. The *mean* value given by Stas is 14·04.

Another instance of the use of large quantities of material is to be found in Morley's determinations of the densities of gases. The accuracy of these experiments, calculated on the basis of the quantities of material used, the errors of weighing, etc., should be of a very high order; but a study of the figures shows that the differences which exist between individual results are far greater than are to be found among those of Lord Rayleigh, who worked with much smaller quantities.

Obviously the mechanical difficulties in the operations of chemistry and physics increase more rapidly than in proportion to the quantities of the substances used; in a given experiment there is generally a certain quantity which can be used with the best result. The

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man who can estimate that quantity by the aid of mathematics, and, when this branch of science finds its limits, by the aid of his own judgment and sense of proportion, is the best experimentalist; and to this class we may refer such scientists as Cavendish, Berzelius, Dumas, Regnault, and certain living men whose work has been, or will be, referred to.

So far we have discussed the underlying principles of the more important chemical reactions which have led to the determination of equivalents. We can now deal with certain physico-chemical methods.

It was proved long ago, by Faraday, that when electric currents of the same strength are passed through electrolytic cells containing solutions of different salts, the quantity of each substance liberated is proportional to its equivalent. Thus, the same current would liberate :—

Element . . .	Silver.	Zinc.	Copper.	Oxygen.	Hydrogen.
Atomic mass . .	108	65	63·8	16	1
Equivalent or quantity liberated	108	32·5	31·7	8	1

Faraday's experiments were only of sufficient accuracy to prove that his law is a very close approximation to the truth, the deviations being attributable entirely to experimental error.

Faraday's experiments were subsequently repeated by a number of other investigators, among them Lord Rayleigh; but they all appear to have come to the conclusion that there is some disturbing influence at work during the process of electrolysis, and that metals like copper and silver are not deposited in the exact proportion of their equivalents. It remained for Richards, of Harvard University, to discover the cause of these deviations, and to devise a means of determining equivalents with accuracy by the electrolytic method.

According to the modern theory of solution, silver nitrate in solution is, as we have already stated, dissociated into $\overset{+}{Ag}$ ions and $\overset{-}{NO_3}$ ions; and during electrolysis these ions move towards the negative and positive poles respectively. If this process were the only one to be considered, it would be impossible to account for the irregularities referred to. However, as we have seen, there is a tendency to form complex ions, the negative ion picking up silver compounds.

Richards found that around the positive pole in the voltameter a small quantity of nitrite was produced, accompanied by solution of the silver plate at which it was formed. The change may be represented by the equation,

$$\overset{-}{NO_3} + 2Ag = \overset{-}{NO_2} + Ag_2O,$$

$\overset{-}{NO_3}$ *ion* + *metallic silver*

$= \overset{-}{NO_2}$ *ion* + *silver oxide*,

a change independent of the electrolysis.

The formation of a complex ion might be represented thus:

$$\overset{-}{NO_2} + Ag_2O = (\overset{-}{NO_2} + Ag_2O)$$

$\overset{-}{NO_2}$ *ion* + *silver oxide* = *complex ion.*

The $\overset{-}{NO_3}$ ion behaves similarly. These complex ions would pass by simple diffusion towards the negative pole, and might undergo further change,

$$(\overset{-}{NO_2}.Ag_2O) = \overset{-}{NO_2} + 2Ag,$$

so that more silver would pass from the positive to the negative plates than served as $\overset{+}{Ag}$ ions to carry the current.

After arriving at this conclusion it was a simple matter to introduce a porous pot of fine biscuit ware between the two poles of the cell, and so restrain the diffusion of the complex silver ions from the positive to the negative poles.

It would serve no useful purpose to discuss fully the source of error in using the copper voltameter. It suffices to state that the result of a similar investigation led Richards to perfect the instrument, and that he found that the ratios of the chemical and electrochemical equivalents of copper and silver are practically identical :—

Chemical equivalent of copper = 31·500
Electro-chemical equivalent of copper = 31·502

Comparatively recently it has been pointed out, by Daniel Berthelot, that it is possible to obtain a close connection between the molecular masses determined by means of gas-densities and the equivalents determined by chemical means.

According to Avogadro's hypothesis, the molecular volume — that is, the volume occupied by a mass of a gas representing the molecular mass expressed in grams— should be the same in all cases. In practice we find that this is not quite true, and that the ratio of the gas densities is not identical with the ratio of the molecular masses deduced from chemical equivalents.

Further, it is known that Boyle's law,

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which states that the volume of a gas at constant temperature varies inversely with the pressure, is not quite true, and that most gases are rather more compressible than the law would imply; hydrogen and helium, however, deviate from the law in the opposite direction. As might be expected, it appears that these two sets of irregularities are of such magnitude that if we calculate the relative densities of gases under very low pressure, we find that they approach to multiples of the chemical equivalents.

Suppose v_0 is the volume occupied by a gram molecule of a gas at the normal pressure p_0 at which its density is d_0, and suppose that at a very low pressure, p, the volume is v. We can then write –

$$\frac{p_0 v_0}{p v} = a\,(p - p_0),$$

where a is a constant for the particular gas. When p is very small, we may write for the molecular volumes two gases –

$$\frac{v_0}{v_0'} = \frac{1 - a p_0}{1 - a' p_0} = \frac{1 - \alpha}{1 - \alpha'}$$

where $\alpha = a p_0$, and $\alpha' = a' p_0$.

For the molecular masses we may write–

$$\frac{m}{m'} = \frac{(1 - \alpha)\, d_0}{(1 - \alpha')\, d_0'}$$

The following result illustrates the application of this principle :—

Gas	Hydrogen.	Nitrogen.	Carbon Monoxide.	Oxygen.
α . . .	−0·00046	+0·00038	+0·00046	0·00076
d_0 . (Oxygen = 1).	0·062865	0·87508	0·87495	1·0
m . . .	2·0147	28·013	28·007	32
m from chemical equivalents	2·016	28·08*	28·007	32

There exists one class of elements of which it is impossible to determine the equivalents, for the reason that these elements are unknown in chemical combination. To this class belong the inactive gases helium, neon, argon, krypton, and xenon.

The equivalent of an element has been defined as a submultiple of the relative atomic mass, and we may write,

Atomic mass = equivalent × valency.

* The value 14·04 for the atomic weight of nitrogen is possibly too high.

Now for these elements we denote the valency as indeterminate, since we have no reason for assuming that it is zero, and consequently the term equivalent has no meaning with reference to them. We may, however, speak of their molecular and atomic masses with perfect propriety.

The approximate molecular masses may be calculated from their densities by means of the Avogadro rule. They are, taking the molecular mass of oxygen as 32 :—

Helium.	Neon.	Argon.	Krypton.	Xenon.
4	20	40	81·5	128

We shall now consider how the atomic masses have been deduced.

According to the kinetic theory of gases, the pressure exerted by a gas on the wall of the vessel containing it is the sum of the impacts of gas molecules. If we consider a mass of gas enclosed in a rigid vessel and supply heat to it, the heat may be entirely absorbed in increasing the velocity of linear motion of the molecules, or may be partly taken up in intensifying the motion of the atoms within the molecule itself. If the molecule comprises one atom only, the latter cannot take place. This is a highly mechanical picture, but it will serve our purpose.

If we take a mass of gas, equivalent to the molecular mass expressed in grams, and heat it through one degree Centigrade under the conditions referred to above (that is, at constant volume), we can calculate from the kinetic theory, that three heat units will be absorbed. For the molecular heat at constant volume we can write

$$C_v = 3.$$

If the constitution of the molecule is such that the atoms in it are capable of free vibrations, then

$$C_v = 3 + x,$$

where x increases as the molecule becomes more complex.

If we now allow our mass of gas to expand till the pressure falls to the original pressure, the temperature remaining constant, it can be shown that two further heat units will be absorbed in doing work against external pressure. For the molecular heat at constant pressure we may write

$$C_p = 3 + x + 2,$$

where in the case of a simple molecule $x = 0$.

The ratio C_p/C_v can easily be determined from the velocity of sound in the gas and from its density by the formula,

$$\frac{v}{v'} = \sqrt{\frac{D'}{D}\,\frac{k}{k'}},$$

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where v is the velocity of sound, D is the relative density at 0° C and 760 millimeters of mercury pressure, k is the ratio C_p/C_v, by the method of Kundt and Warburg; some gas like air, for which D and k are known, being taken for comparison. The method need not be described in detail.

The value of k for a gas in which the molecules contain single atoms is $5/3 = 1{\cdot}67$, and this is found to be the case of the inactive gases, the vapour of mercury and of some other substances. In these cases the molecular and atomic masses are identical.

In the case of complex gases,

$$k = (5 + x)/(3 + x),$$

or less than $1{\cdot}67$. The value of k for oxygen and hydrogen is $1{\cdot}4$, so that the molecules must in these cases contain more than one atom, and the simplest molecular formulæ which can be assigned to them are O_2 and H_2.

The "Periodic System" and its bearing on our choice of atomic masses has been fully discussed by Sir William Ramsay, K.C.B., in an article which has appeared in TECHNICS.* I shall only refer to this subject to point out that the inactive gases fall into that group of elements of which the valency sometimes rises to eight or possibly falls to zero. The probable atomic masses of these elements, of indeterminate or possibly zero valency, we have just discussed.

Long before the periodic law took form, two important relationships were discovered which have been of considerable use to us in finding the atomic weights. The law of Dulong and Petit states that the atomic heat of the elements has a constant value, about $6{\cdot}4$. The atomic heat (the product of the specific heat into the atomic mass) is, however, variable with temperature, and only in the case of gases are the rates of variation at all similar; carbon shows some remarkable abnormalities. The relationship is, however, sufficiently general to be of use.

The second generalisation is that of Mitscherlich, and is called the "Law of Isomorphism." It was at first supposed that similarly constituted substances had often exactly the same crystalline form. It has since, however, been shown that this is not exactly true, and that in the so-called isomorphous series we have small divergences in the crystalline forms, usually in the direction of increase or decrease in atomic mass of the element present. Exceptions are to be found among crystalline bodies belonging to the regular system. The following are instances of isomorphous series:—

Sodium and the alkali metals in their chlorides, bromides, and iodides.

Calcium, strontium, and barium carbonates.

Iodine and manganese in periodates and permanganates.

Sulphur, selenium, tellurium, and chromium in sulphates, chromates, etc.

Many other examples can be found. Since the compounds forming these series have analogous compositions and similar crystalline forms, it follows that they will probably be similarly constituted, and that the relationships between the equivalents and atomic masses of the elements present in them will be identical.

There is an interesting relationship between the atomic masses of the elements and the character of their spectra. In 1885, Balmer showed that the values of the wave lengths of the lines in the hydrogen spectrum form a definite series, which can be expressed by a formula such as $\frac{1}{\lambda} = A - \frac{B}{n^2} - \frac{C}{n^4}$, where λ is the wave length, n is the number of the line in the series, and A, B, C, are constants.

Later, Kayser and Runge showed that similar relationships existed between the lines in the spectra of other elements, but that in most cases it was necessary to consider the lines as falling into three separate series, of which the members consisted either of single lines, or more usually of pairs of lines. The "principal series" contained the strongest and brightest lines; the "first subordinate series" contained strong but hazy lines; and the "second subordinate series," weaker lines. When there are pairs of lines, the difference between the values of $1/\lambda$ for the lines constituting the principal series diminishes as we move towards the violet end of the spectrum; the difference between $1/\lambda$ for the first pair of lines in the principal series is identical with the constant differences in the values of $1/\lambda$ for all pairs of lines in the two subordinate series. We will call this value δ.

Now if A, A′ are the atomic masses of the elements in a series like that of the five alkali metals, we find that the values $\frac{\delta}{A}$, $\frac{\delta'}{A'}$ are nearly identical so far as sodium, potassium, rubidium, and cæsium are concerned. In the case of lithium, the spectrum consists of single lines, so that $\frac{\delta}{A}$ is indeterminate.

It is also observed that the increase in atomic weight in the series is accompanied by

* "The Periodic Arrangement of the Elements." By Sir William Ramsay, K.C.B., F.R.S. TECHNICS, Vol. I., No. 6, June, 1904.

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a shifting of the lines in the spectrum in the direction of low refrangibility.

The case of helium is of particular interest, as the lines in the spectrum furnish two complete sets of series, each consisting of a principal series and two subordinate series. Runge and Paschen, the discoverers of this fact, brought it forward as evidence of two separate elements in helium, the denser one characterised by the yellow line D_3, the other by a very bright blue-green line. They believed at the time that they had succeeded in separating the two gases by the process of diffusion, and showed vacuum tubes filled with so-called "green helium," and "yellow helium." It was shown by the author that this difference could be produced by merely altering the pressure in the tubes: subsequent experiments have failed to effect the separation, and they thus point to the homogeneity of helium.

Similar relationships between the band spectra of elements which do not give bright line spectra are known to exist.

In concluding this article, I can only point out that a thorough study of the basis of atomic mass determinations involves nothing more nor less than a survey of modern chemistry in all its branches. This is hardly within the scope even of a single volume.

SPECIAL DEVICES USED IN WEAVING.

Part II.—Differential Driving Motions for Pirn (or Weft) Winding Machines.

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By HARRY NISBET, Head of the Weaving and Designing Department, Municipal Technical School, Bolton.

IN the manufacture of some fabrics, coloured and bleached (white) weft is employed. Such weft may be either dyed or bleached when in the form of cops; but it is more frequently submitted to these processes when in the form of hanks, and subsequently re-wound on to paper tubes, or else on to wooden pirn bobbins (as shown in Fig. 5) by means of a pirn winding machine, of which there are many varieties. Pirn winding is also resorted to for grey weft when this is supplied in any form that is unsuited to the shuttle by which it will be woven; and, also, when cops of weft are not of sufficiently firm build to enable them to withstand the shocks of a shuttle on reaching its destination in a shuttle-box during weaving.

Fig. 5. Pirn Bobbin.

In the previous article under this head, the importance of winding warp yarn at a uniform velocity and tension was indicated. For different reasons it is, at least, as important that weft yarn also should not be subjected to varying degrees of tension during its transformation from any preliminary stage to another. In many, if not in most woven fabrics, weft plays a more conspicuous part than warp, and contributes chiefly to their fulness, bulk, and weight; but it does not require to be so strong as warp yarn, which bears all the severe straining of shedding and beating-up during weaving; hence weft is generally produced coarser and softer than warp, and is, therefore, more susceptible to tensile strain. For these reasons it is important that all the essential properties of weft, as regards fulness and regularity, should be preserved during winding; and, also, that yarn should be placed compactly upon tubes or bobbins, so as to avoid the evils resulting from soft or imperfectly wound bobbins.

The attainment of these objects does not present the same difficulties in "pirn" winding machines as in "cop" or "spindle" winding machines, owing to the very different conditions which obtain in these systems. It will be remembered that in a cop winding machine, yarn is built upon a bobbin tube by successive and, more or less, *parallel layers*, *placed exactly one above another*, and thereby gradually increasing its girth. In pirn winding, however, yarn is built upon a bobbin of very different form, by short successive *conical layers*, each of which is placed a *little beyond the preceding layer*, along the bobbin, without increasing its girth, thereby causing yarn to be wound upon a conical surface, which is *uni-*

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formly the same from beginning to end of winding. This latter circumstance is highly favourable to the differential driving of bobbins, to compensate for their varying diameter between the extremities of the cone.

In most pirn winding machines spindles and bobbins are driven at a uniform velocity, thereby causing yarn to be wound at a variable speed, namely, slower as it passes on to the small diameter of the cone, and at an accelerating pace as it approaches the larger diameter—the ratio of velocities being about one to two respectively—thereby winding yarn at a variable tension. This defect appears to be generally recognised by machine makers, who are constructing pirn winding machines with differential driving motions, whereby the velocity of spindles and bobbins is proportionately retarded as guide rails approach the major diameter of the bobbin cone, and accelerated as they approach the minor diameter of the cone, thereby winding yarn at a uniform velocity throughout.

Many ingenious mechanical devices have been invented to accomplish this object. These are applied both to disc winding machines, in which pirn bobbins are driven by surface contact with bevelled discs (as in Figs. 6 and 7), and also to those in which bobbins rest either in metal pirn cups (as in Fig. 8), or against one, two, or three conical rollers, and are rotated by means of spindles entering wharves that are driven by means of cotton bands from a tin drum.

A differential driving motion of a disc pirn winding machine is illustrated diagrammatically in Fig. 6. This machine contains two driving shafts, L and L', placed one on each side of the machine, and each containing a number of bevelled metal discs, M M', against which bobbins N are held in close contact by means of spindles O. The shafts and discs are driven at a differential velocity (to compensate for the varying diameter of a bobbin cone) by means of a large wheel H, which is also driven differentially in a manner to be presently described.

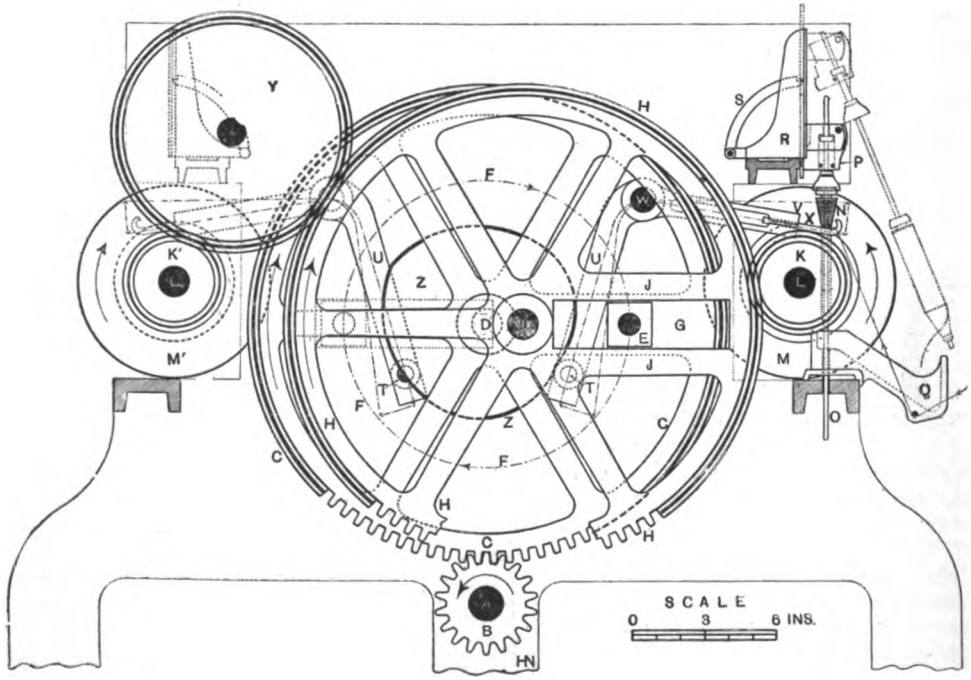

FIG. 6.—DIFFERENTIAL DRIVING MOTION OF DISC PIRN WINDING MACHINE.

Motion is conveyed to all parts of the machine by means of a pinion wheel B on shaft A, which latter also contains the driving and loose pulleys. The pinion B drives a large spur wheel C, which rotates at a uniform velocity upon a short stud or shaft D (shown in dotted line). Projecting from an arm or spoke of wheel C is a square lug E, which revolves around stud D in a path indicated by dotted line F. The path of the lug is *concentric* to the centre of stud D, and, therefore, always the same distance from it.

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A little in front of wheel C is another similar wheel H, which rotates upon stud I, fixed in the same horizontal plane, and on the right of stud D, with a distance of one inch and a half between their centres. Between two parallel arms J, of wheel H, is a slot G for the reception of lug E, which drives wheel H at a differential velocity by reason of the lug moving in a path that is *eccentric* to the stud I, on which wheel H rotates, and at an ever-varying distance between the lug and stud I. Thus, when the lug is on the extreme right of stud I, it is nearest to it, and therefore, drives wheel H at its maximum velocity (when yarn is passing on to the thinnest part of a bobbin cone), and, per contra, when on the extreme left (being farthest from the stud), it drives wheel H at its minimum velocity (when yarn is passing on to the thick part of the cone), the ratio being inversely proportionate to the distance between the centres of the lug and stud I. As the lug travels from right to left, the velocity of the discs M, M' is gradually retarded; and as it travels from left to right their velocity is gradually accelerated—their retardation and acceleration being coincident with the rise and fall, respectively, of guides X, thereby winding yarn at a uniform velocity at all points along a bobbin cone. If it is desired to make thicker or thinner bobbins by causing guides X to move through a longer or shorter distance, the degree of eccentricity in the velocity of discs M, M' may be increased or diminished accordingly, by fixing the lug (which is adjustable) respectively nearer to or farther from stud I.

Yarn is guided up and down along a bobbin cone at a uniform pace, by means of guides X, carried by arms V, and actuated by two cams Z (one for each row of guides, and of which only one is shown in the diagram). The cams are fixed in different positions upon the shaft D of wheel C, and act upon runners T secured near the ends of arms U, which are fixed at one end of shafts W. Arms V, carrying guides X, are also fixed upon the same shafts, hence, as the cams revolve, their respective guides rise and fall alternately and simultaneously.

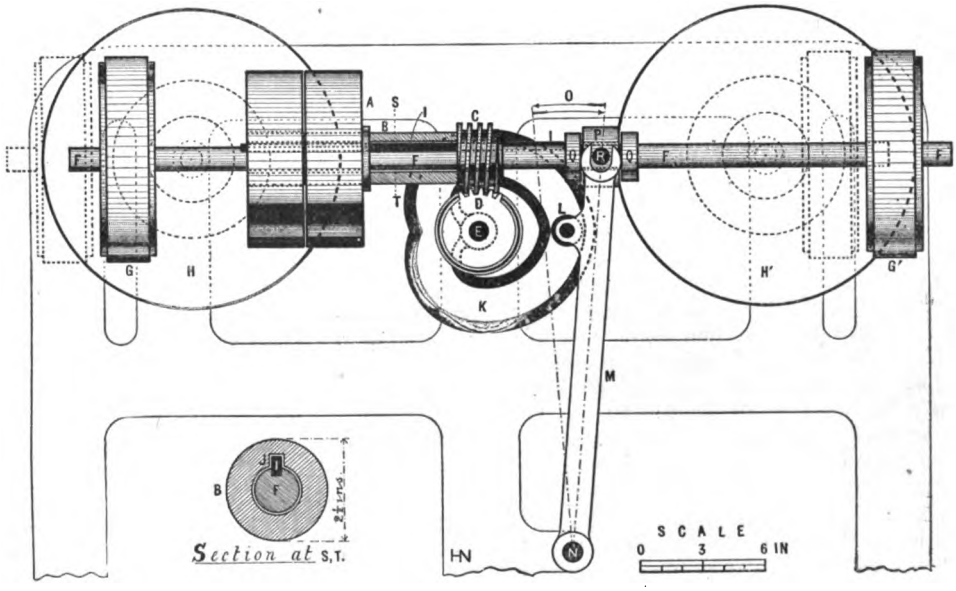

FIG. 7.—A SECOND TYPE OF DIFFERENTIAL DRIVING FOR DISC PIRN WINDING MACHINE.

Spindles O are each suspended from a holder P, which slides in two vertical grooves, one on each side of bracket R. The lower portion of a spindle passes freely through a hole in a bolster Q, so as to hold its bobbin against a disc. As a bobbin becomes filled with yarn it rises automatically, until the bobbin is full, when its spindle is withdrawn from the hole, and slides down an inclined surface of the bolster, thereby carrying its full bobbin out of contact with the revolving disc. As a spindle slides down a bolster the spindle holder P is caught in its descent by a catch S, fulcrumed on bracket R, thereby enabling a spindle to be pulled forward by the operative (as indicated by dotted lines), to permit of the removal of a full bobbin, and its replacement by an empty one, after

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which the spindle and bobbin are lowered to re-commence winding. It will be observed that wheel H gears directly with a small wheel K on the end of shaft L, but that it drives shaft L′ through the medium of a simple carrier wheel Y and wheel K′. This has the effect of driving shafts L, L_1 and their discs M, M′ in opposite directions, thereby causing bobbins on both sides of the machine to turn in the same direction, so that all threads pass on to their respective bobbins on the side that is in contact with their driving discs.

Another type of a differential driving motion for a disc pirn winding machine is represented in Fig. 7. In this machine the shafts carrying the bevelled discs (shown in dotted lines) on each side of the machine are driven frictionally, and therefore negatively, by means of bowls G, G′, having leather or compressed paper driving surfaces, which bear against large circular plates or discs H, H′, fixed at one end of each driving shaft. By driving the discs negatively, instead of positively (as in Fig. 6), they are liable to lose speed, in consequence of the driving surface of friction bowls slipping on their respective plates, as the bowls become either worn or unfavourably affected by atmospheric variation of temperature and humidity.

Motion is conveyed to all parts of the machine by means of a pulley A, keyed upon a hollow shaft or sleeve B (shown in part section), which also carries a worm C, whose thread drives a worm wheel D, on stud E. Passing freely through sleeve B is a long shaft F, at whose opposite extremities the friction bowls, G, G′ are fixed so that they always bear against their respective plates H, H′, on the ends of the disc shafts. In the portion of shaft F which enters the sleeve B is fixed a long feather-key I, loosely fitting into a key-way or channel J, cut out of the sleeve, as indicated in the diagram (Fig. 7), showing a transverse section at S T. The object of this contrivance is to enable shaft F to be rotated by sleeve B, and, at the same time, to permit of the shaft, with its friction bowls G, G′, sliding in a lateral direction from side to side (as indicated by full and dotted lines), so as to cause the friction bowls to bear on the plates at varying distances from their centres, and thereby drive them at a differential velocity consistent with the variation in the diameter of a bobbin cone. The lateral movement is imparted to shaft F by means of a positive-acting cam K, fixed on stud E. As the cam revolves it acts upon a runner L, fixed to a vertical lever M, fulcrumed at N, so as to cause the lever to slowly oscillate, as indicated by arrows O. The upper extremity of lever M is forked, so as to span a loose collar P, encircling shaft F between two fixed collars, Q. Each branch of the fork is slotted to receive a pin R, projecting on each side of the loose collar; hence, as lever M oscillates, shaft F moves from side to side as described. On stud E are fixed two other cams (not shown), to operate guides on each side of the machine. These two cams, and cam K, revolve in unison, and are so fixed in relation to each other that yarn passes on to the large diameter of bobbin cones when friction bowls G, G′ are farthest from the centres of plates H, H′, and the latter are driven at their minimum velocity; and, per contra, yarn passes on to the small diameter of bobbin cones, when friction bowls are nearest to the centres of their plates, and the latter are driven at their maximum velocity, thereby winding yarn at a uniform velocity at all points along a bobbin cone.

A third, and last, example of a differential driving motion is illustrated in Fig. 8. It is based upon similar mechanical principles to that shown in Fig. 6, and, like that, is positive acting. Unlike the two previous motions, however, which are applied to *disc* winding machines, the present one is adapted to a machine in which bobbins 8 are built up within metal pirn cups P, arranged in two rows, one on each side of the machine, and fixed upon rails 5.

In machines of this type a tin drum M, supported at intervals by short shafts L, passes centrally down the machine, and drives, by means of driving bands N, a number of wharves O, which rotate upon hollow studs fixed at regular intervals apart upon rails 4. Passing centrally through each wharve is a rectangular hole, to freely receive the lower portion of a spindle shank 6, whose cross section is counter to the hole. Spindles are provided with a heavy head-piece 7, having projections that fit into a groove in a bobbin head. Thus, by inserting a spindle through a bobbin and wharve, the bobbin is rotated until it is filled with yarn, when it withdraws its spindle from the hole in its wharve (as indicated on the left of the diagram), and stops automatically. The function of the driving motion under present notice is therefore, to drive wharves O at a differential velocity, coinciding with the varying diameter of a bobbin cone, which object is accomplished in the following manner.

On the first driving shaft A, which con-

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tains driving pulley 1, is a pinion wheel B, which drives a large spur wheel C. The hub D, of wheel C rotates upon a large tubular stud or bearing E, which is so constructed as to permit of a shaft I passing through it on the right, with a distance of two inches and a quarter between their axes. Carried upon an arm of wheel C, at a point near the rim, is a runner F, which enters a slot G formed at one end of an arm H, keyed to shaft I, to which is also keyed a wheel J, that drives tin drum M by means of a wheel K, fast upon one end of the tin drum shaft. As wheel C and cam Q all revolve at the same velocity around the axis of shaft I. The cam Q acts upon a runner R carried at the lower extremity of a lever S, fulcrumed at T. By means of two connecting links V, attached to a stud U, secured to lever S, the latter is connected to two arms W, secured to one end of shafts X, which extend on each side for the full length of the machine, and carry a number of bracket arms Y to support guide-rails Z. The adjustment and timing of the various parts are such that, when runner F is nearest to shaft I (at which time bobbins are revolving at their maximum velocity), guide-rails are passing yarn on to the least diameter of a bobbin cone; and, per contra, when the runner is farthest from shaft I (as indicated by dotted line, and at which time bobbins are revolving at their minimum velocity), guide-rails are passing yarn on to the greatest diameter of a bobbin cone. Thus, as cam Q revolves, guide-rails Z are caused to rise and fall (as indicated by dotted lines), coincidentally with the retardation and acceleration of the velocity of spindles respectively, thereby ensuring a uniform rate of winding yarn upon bobbins, irrespective of the varying diameter of a bobbin cone.

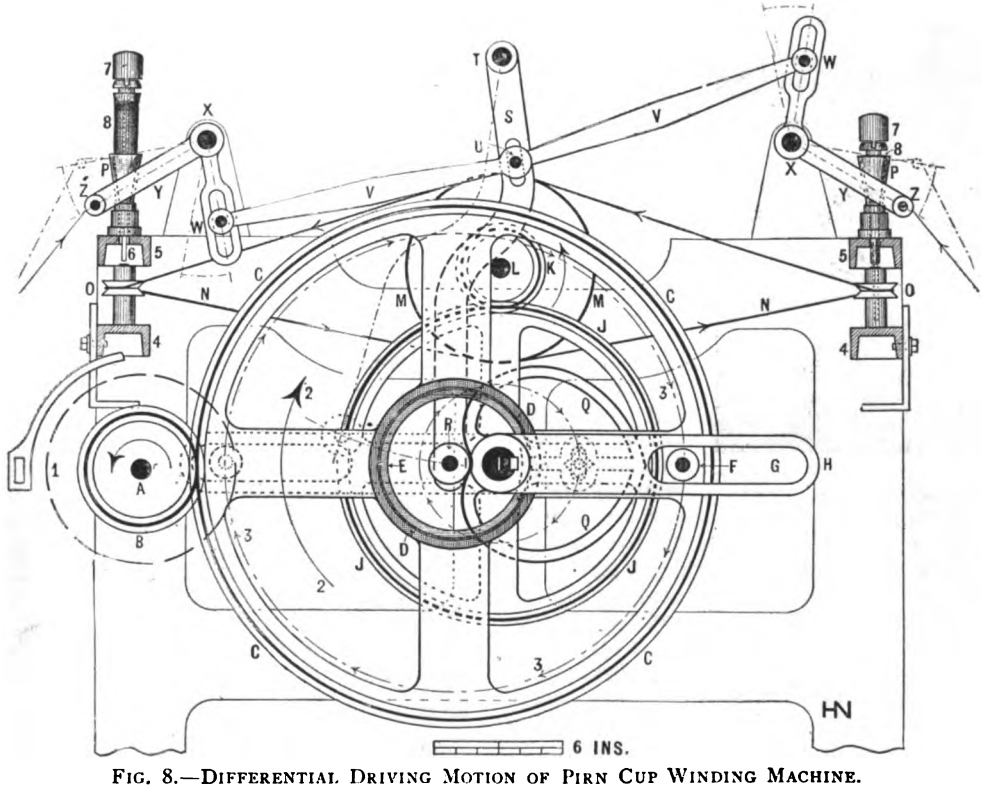

FIG. 8.—DIFFERENTIAL DRIVING MOTION OF PIRN CUP WINDING MACHINE.

revolves in the direction indicated by the arrow 2, the runner F revolves in a path which is *eccentric* to the shaft I (as indicated by arrows 3), hence, the runner acts upon arm H at a constantly varying distance from the centre of shaft I, to which the arm is keyed, thereby imparting to wheels J, K, tin drum M, wharves O, spindles 6, 7, and bobbins 8, a differential velocity.

Threads are guided on to their respective bobbins by means of guide rails Z, which slowly rise and fall in front of pirn cups P. Guide rails are actuated by a heart cam Q, bolted to a spoke of wheel J, and having shaft I for its axis; hence, arm H, wheel J,

(*To be continued.*)

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CAPTIVE BALLOON PHOTOGRAPHY.

By GRIFFITH BREWER.

FIG. 1.—DINGHY CARRYING REEL AND HOLDING BALLOON CAPTIVE.

HITHERTO balloon photographs have only been taken of chance subjects, because free balloons drift with the wind and, therefore, seldom bring the photographer within range of the objects he wishes to photograph; and when by some lucky chance the balloon does drift over an object of interest, the altitude of the balloon at the moment is probably too great to allow of more than a misty view being secured.

Photographs of the desired objects taken from aloft can, of course, be obtained from a captive balloon if an ascent be made from a suitable position relatively to the object to be photographed; but it is only in rare situations that a sufficient supply of gas can be obtained for the purpose of a balloon ascent; and if ordinary captive ascents have to be made, not only is the cost of at least 30,000 cubic feet of gas and the hire of the balloon to be considered, but also the cost of an engine for hauling the balloon up and down must be taken into account. Besides, a photographer who is desirous of taking panoramic views may sometimes hesitate before suspending himself a thousand feet in the air from a glorified gas bubble; and even when this is no serious impediment, experience has shown that a good aeronaut is often a bad photographer, whilst a good photographer is still more frequently a bad aeronaut; and the possession of both these accomplishments being essential to good results, it generally happens that the photographs leave much to be desired.

The natural result of all these difficulties is that, although we often see reproductions of photographs taken from balloons, they are generally of objects of small interest, and, in the majority of cases, are of a misty and unsatisfactory character.

Now, if we could arrange everything so that the photographer need not go aloft to press the button, the balloon can be relieved of the weight of the usual passengers and car, and need only lift the camera itself; then the difficulties of gas supply would be avoided, as the ordinary household gas meter could deal with the inflation of a balloon sufficiently large for this purpose. The hire of the balloon is a difficulty that would also disappear, because the reduction in its cost brings it within range of the much talked-of man of moderate means, and the photographer is left free to choose his own weather and time of ascent without having to make engagements beforehand with a skilled aeronaut.

I will now endeavour to show how this

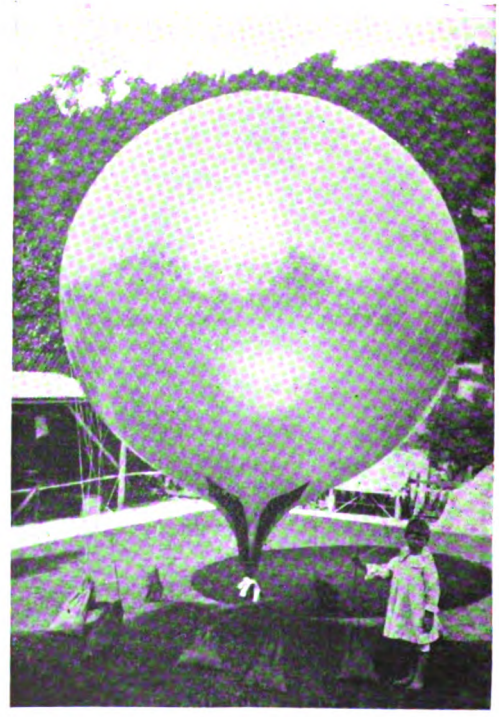

FIG. 2.—THE BALLOON AFTER INFLATION.

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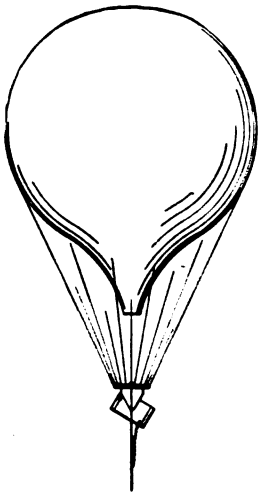

FIG. 3.—BALLOON WITH CABLE ATTACHED.

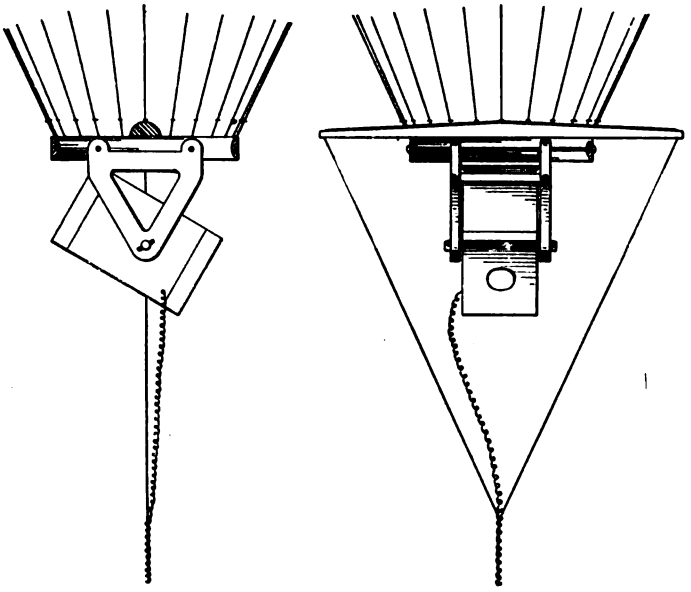

FIG. 5.—TWO VIEWS SHOWING METHOD OF ATTACHING CAMERA TO HOOP.

may be accomplished, by describing experiments I have made during the past summer.

The balloon shown in Figs. 2 and 3 is of 500 cubic feet capacity, and takes two hours to inflate through an ordinary 16-light gas meter. It is spherical in form, and is made of goldbeater skin; a net provided with the ordinary leading lines is employed for covering the envelope and for attaching to the hoop. The camera is one of box form, with half-plate dark slides focussed at infinity; the camera has screw-clamped trunnions at its sides (Fig. 5) mounted in triangular side frames so as to enable it to be set at any angle required. The lens is fitted with a Bausch and Lomb shutter (Fig. 6); in setting the shutter a hook is caused to hold it, until such time as the hook is withdrawn by an electro-magnet, when the shutter is released and the exposure made. The 500 feet of captive line carries two rubber-covered flexible conductors which, with the captive line, are made up together into one cable, and wound on a reel (Fig. 4) running on ball bearings, the inner ends of the two wires being connected with a plug terminal on the reel to enable a battery circuit to be connected. An electric switch on the battery controls the time of transmission of the current for actuating the shutter covering the lens.

When the balloon has been inflated the

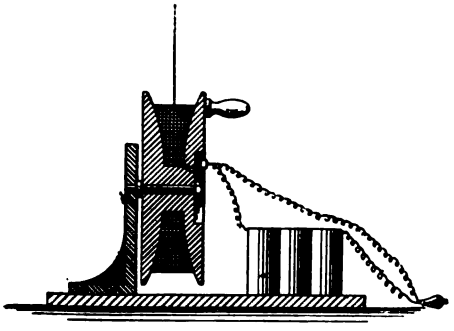

FIG. 4.—SECTION OF REEL USED FOR WINDING IN THE CABLE SHOWN ATTACHED TO BALLOON IN FIG. 3.

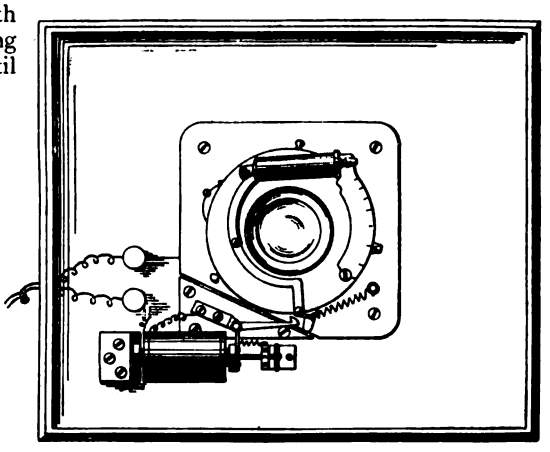

FIG. 6.—BAUSCH AND LOMB SHUTTER, OPERATED MAGNETICALLY.

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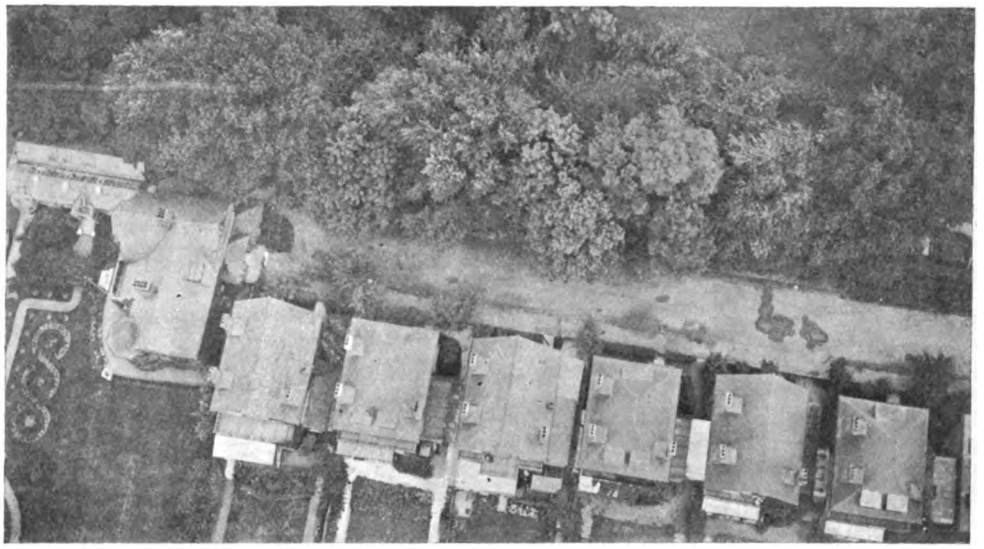

FIG. 7.—BIRD'S-EYE VIEW OF SEVEN HOUSES AND ROAD, TAKEN FROM AN ELEVATION OF 500 FEET.
The dark stain on the road marks the spot where a motor car had just previously been washed.

hoop is attached to the leading lines, and the swing frame of the camera is inserted in the hoop, to which it is connected firmly by means of two long bolts. The captive line is then attached to a bridle connected to a cross bar on the hoop, and the wires are passed into the front partition of the camera and fastened to the terminal screws of the electro-magnet.

The dark slide is now inserted and its front removed, and the shutter is set and held ready by the hook. We next turn the camera on its trunnions, with the lens pointing downwards if a true plan view is desired; and on releasing the reel the captive rope is let out and the balloon under its own lifting power runs up swiftly until checked by applying a break to the reel. On stopping the reel after the balloon has risen to 150 feet, the connection plug is inserted, and

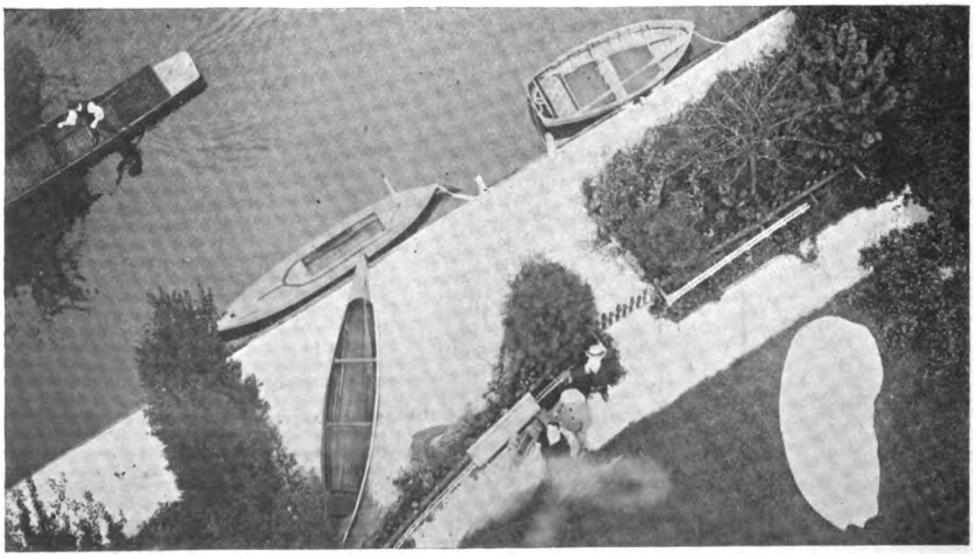

FIG. 8.—BIRD'S-EYE VIEW OF BROOMWATER CREEK, FROM AN ELEVATION OF 160 FEET.
The figures on the path represent the operators in charge of the balloon.

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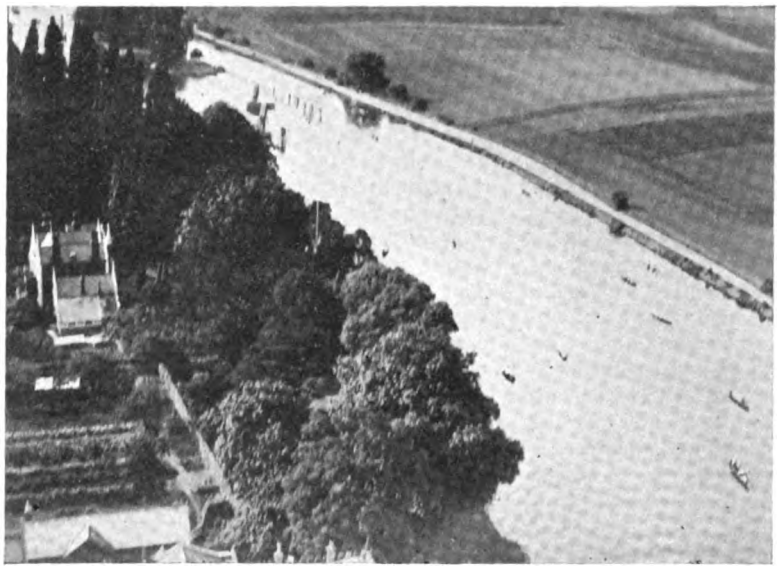

FIG. 9.—VIEW OF THE THAMES, NEAR TEDDINGTON LOCK.

standing on the white path represent those operating the balloon: and the reel containing the captive line and conducting wires is shown on the seat where the box containing the batteries is also carried. The curious white loop on this photograph in the centre of the picture is a portion of the captive line situated near the lens: this defect usually occurs when taking photographs vertically below the camera. The white patch on the grass to the right of the picture is the cover belonging to the dinghy, spread out on the grass to dry.

then, on pressing the button, an electric current is sent through the 1000 feet of wire conductor suspended in the air and wound on the reel; the magnetic release is thus operated, and the exposure of the plate effected.

After hauling the line in on the reel until the balloon is on the ground, the shutter is re-set, the plate changed, and the balloon is run up a second time in order to take a new view. This time we let it up to 500 feet, and the roofs of seven houses are included in the view (Fig. 7); the garden from which the balloon was let up belongs to the house number three from the left-hand side of the picture.

Instead of taking a view of the house end of the garden on the next occasion, we take a view of the bottom of the garden which abuts on Broomwater Creek, running into the Thames, and the balloon in this instance is run up to a height of 160 feet before pressing the button. In this view a man is seen punting along the creek, and one canoe and a dinghy are tied up to the landing-stage, another canoe being shown lying on the landing stage. The three figures

All the above photographs were taken with the lens pointing nearly vertically downwards; now, in order to get a wider view, after hauling the balloon down, we set the camera

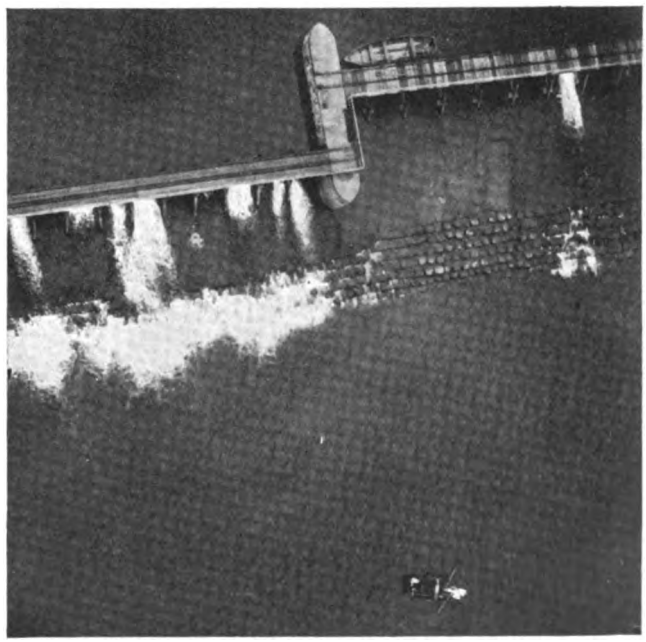

FIG. 10.—BIRD'S-EYE VIEW OF TEDDINGTON WEIR FROM AN ELEVATION OF 500 FEET.

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almost horizontally with the lens pointing in the direction of Teddington Lock, which is situated about half a mile from the garden. The balloon is then let up and the next picture (Fig. 9) is taken, where the Thames, with several boats on it, is shown, and Teddington Weir is seen in the distance. The patch of poplars is on the island at Teddington Lock.

In taking captive balloon photographs one could, of course, carry the inflated balloon to objects one wishes to photograph along any public road or across fields; but as the garden from which these experiments were conducted is on the river, by using a dinghy we can conveniently use the Thames as our highway, and so avoid a crowd whilst visiting adjoining places. Fig. 1 shows the dinghy carrying the reel and holding the balloon captive.

The next illustration (Fig. 10) is a plan view of Teddington Weir, taken from a height of 500 feet. The weir is situated half a mile from our last view, the wind causing the balloon to tow the dinghy to the position from which a plate was last exposed. The boat seen in this picture was situated below the weir, and the water can be seen running through the sluices and splashing on the stones on the lower side.

It must not be imagined that the foregoing results were obtained at the first attempt. The first balloon was not the right size, the conductors were not the right gauge, and the camera was far from satisfactory. Experiments extending over many months, however, have overcome all these difficulties, until now, given a fairly calm, bright day, photographs as good as the present ones may be taken with moderate certainty.

A NOVEL TELEPHONE ACCESSORY.

A USEFUL adjunct to the telephone, called the *Telaupad*, has recently been put on the market by Cutmore's Patent Syndicate, of 115, Queen Victoria Street, London, E.C. This consists of a rubber contrivance (Fig. 1) which can be fitted over the telephone

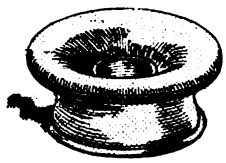

FIG. 1.—THE TELAUPAD.

receiver, as shown in Fig. 2; it adapts itself to the shape of the ear without undue pressure, and so excludes all extraneous sounds. Consequently the telephonic message can be heard much more distinctly than would otherwise be possible, and without the painful sensation produced by pressing the hard case of the receiver against the ear. In addition to this advantage, there is another of scarcely less importance: the selective resonance which produces so much trouble in connection with the ordinary telephone, causing some words or parts of words to be

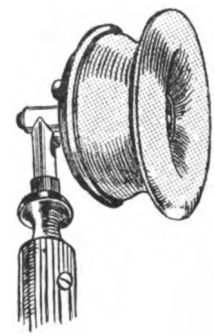

FIG. 2.—TELAUPAD APPLIED TO TELEPHONE RECEIVER.

more distinctly heard than the rest of the message, is much diminished.

The advantage gained by the use of this contrivance is so well marked that the Telaupad is sure to be welcomed by users of the telephone.

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THE MECHANICS OF HEAVY ELECTRIC TRACTION.

PART III.—ACCELERATION (*continued*).

By H. F. PARSHALL, M.I.C.E., M.I.E.E., and H. M. HOBART, M.I.E.E.

THE characteristic of a series motor plays an important part in determining the form of the upper part of the acceleration curve: this occurs from the point where the resistance in series with the motor has finally been completely cut out. From this point onward the speed increases at a slower rate which is a function of the motor's speed curve, the current falling off as the speed increases, until the watts input falls to

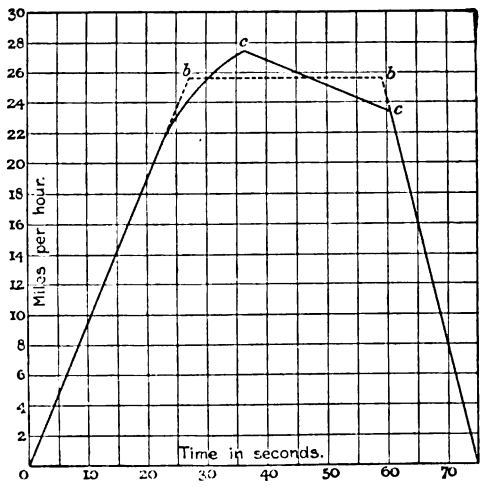
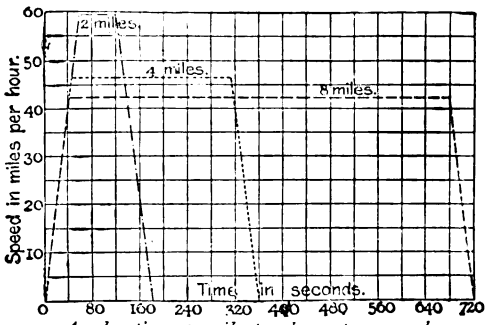
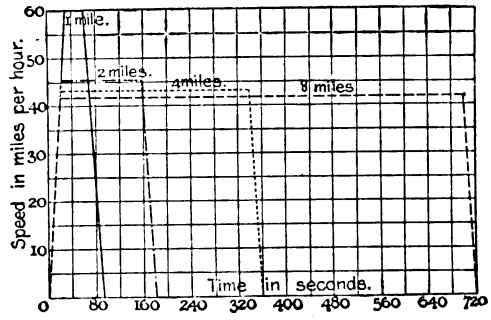


FIG. 23.—TO ILLUSTRATE METHOD OF RUNNING ON MOTOR CURVE.

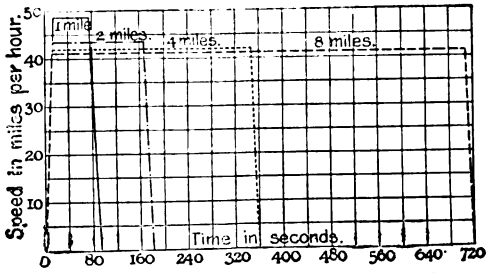
the value required to overcome the train resistance at constant speed. It is frequently the case that the resistance is completely cut out before more than two-thirds of maximum speed is reached, and the remaining one-third is run on the motor curve. The point where operation on the motor curve commences is a function of the design of the motor and of the rate of acceleration employed. This must for the present be overlooked, as it would hopelessly involve the preliminary study of the Mechanics of Heavy Electric Traction, were it necessary to introduce at this stage the varying conditions peculiar to the use of several types of motor, or even to consider the varying characteristics of motors of the same class. The thorough study of this matter of accceleration on the motor curve must be taken up at a later stage. The difference introduced in



Acceleration, 1 mile per hour per second.



Acceleration, 2 miles per hour per second.



Acceleration, 3 miles per hour per second.

FIG. 24.—SPEED-TIME CURVES FOR MEAN SPEED OF 40 MILES PER HOUR.

the speed-time curve for the case already illustrated by the diagrams in Figs. 14 and 15* is seen in Fig. 23, where the case of running on the motor curve is shown in the curve

* TECHNICS, No. 11, November, 1904, p. 427.

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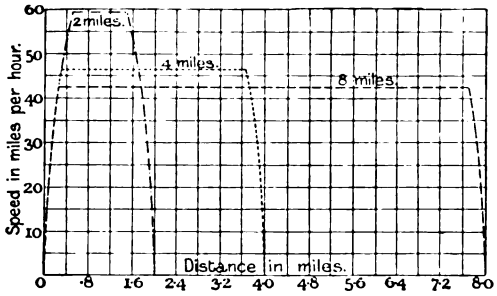
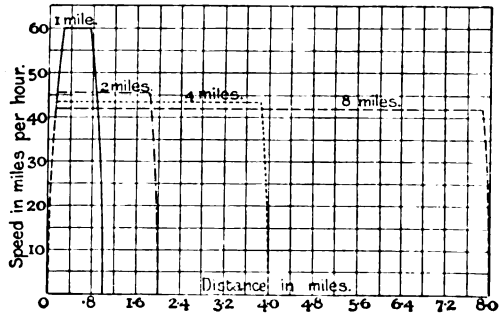
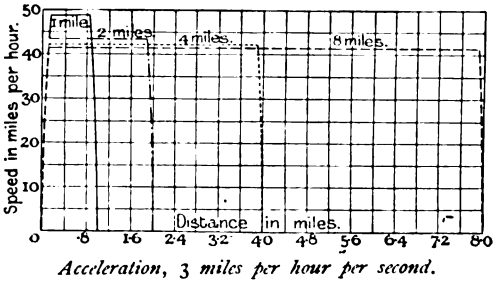


Acceleration, 1 mile per hour per second.



Acceleration, 2 miles per hour per second.



Acceleration, 3 miles per hour per second.

FIG. 25.—SPEED-DISTANCE CURVES FOR MEAN SPEED OF 40 MILES PER HOUR.

o *c c* 75, which may be compared with the curve o *b b* 75, drawn in dotted line, which is reproduced from Fig. 15. As we shall see later, the cycle o *c c* 75 requires the lowest maximum input and the lowest total input for maintaining the specified service, and it is a point of great economic importance to accelerate on the motor curve to the extent permissible with high accelerating rates. For an equipment employing a given design of motor, the higher the initial accelerating rate the sooner will the series resistance be cut out, and the sooner will the point of economical acceleration on the motor characteristic be reached. The average rate of acceleration and the average schedule speed between stops will, however, be the more greatly reduced the sooner the point of

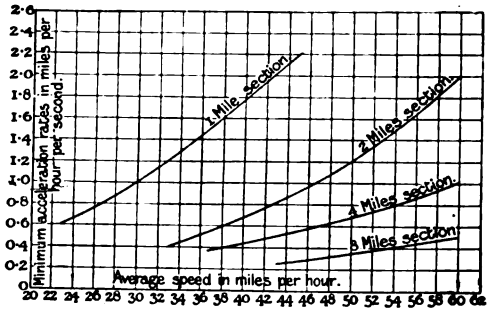

Minimum acceleration rates in miles per hour per second.
1 Mile section.
2 Miles section.
4 Miles section.
8 Miles section.
Average speed in miles per hour.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62

FIG. 26.—MINIMUM ACCELERATIONS FOR GIVEN AVERAGE SPEEDS.

acceleration on the motor characteristic is reached.

While the complete groups of curves corresponding to two, four, and eight-mile sections cannot conveniently be reproduced in these articles, it will be of interest to reproduce portions of them re-arranged for contrast with the curves for the one-mile section.

In Figs. 24 and 25 are shown, for a mean

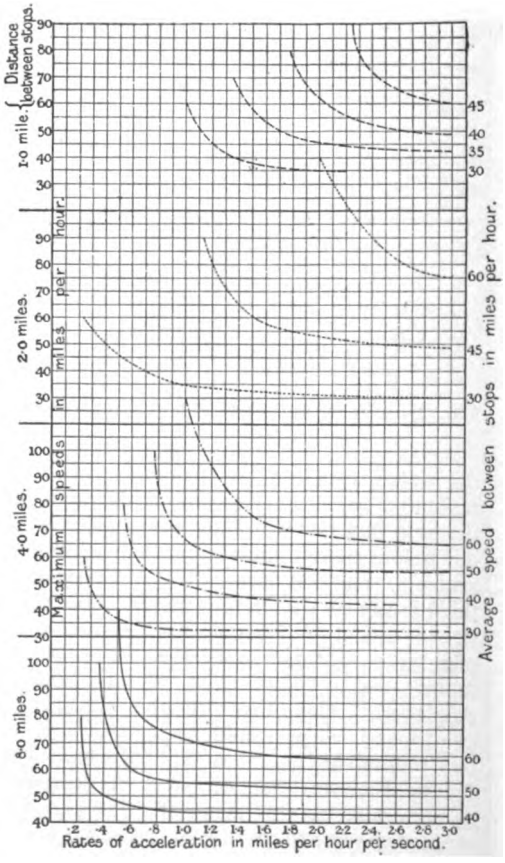

Distance between stops.
1.0 mile.
2.0 miles.
4.0 miles.
8.0 miles.
Maximum speeds in miles per hour.
Average speed between stops in miles per hour.
Rates of acceleration in miles per hour per second.
.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0

FIG. 27.—MAXIMUM SPEED CURVES FOR VARIOUS ACCELERATIONS AND AVERAGE SPEEDS.

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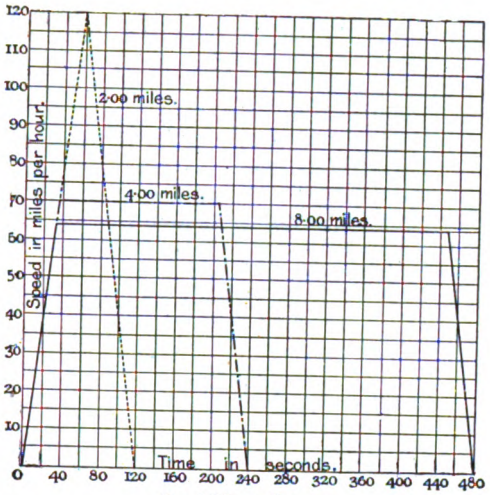
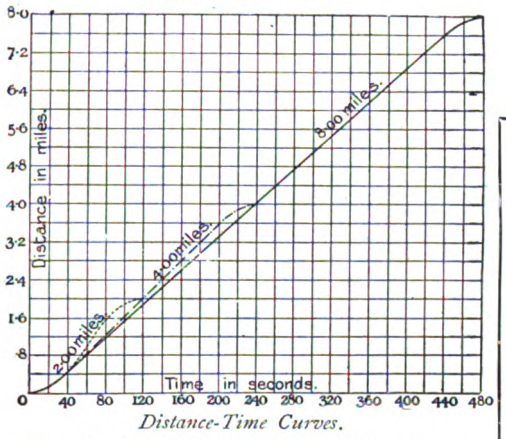
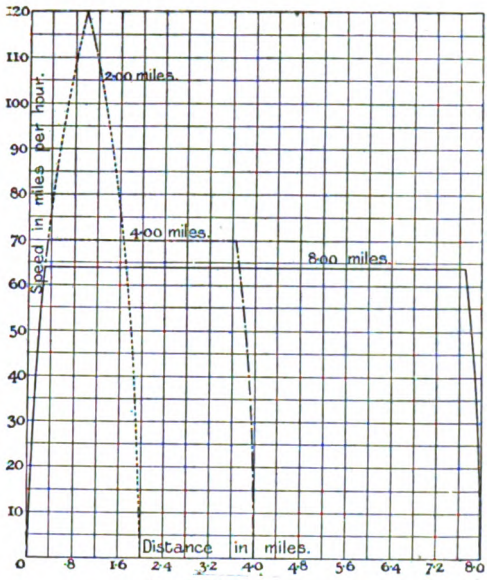


Speed-Time Curves.



Distance-Time Curves.

FIG. 28.—SPEED-TIME-DISTANCE CURVES FOR ACCELERATION OF 2 MILES PER HOUR PER SECOND, AND A MEAN SPEED OF 60 MILES PER HOUR BETWEEN STOPS.



Speed-Distance Curves.

speed of 40 miles per hour, the speed-time (S.-T.) and speed-distance (S.-D.) curves for accelerating rates of one, two and three miles per hour per second. Similar charts for other speeds have been worked out, but are not reproduced in this article.

From a comparison of these various curves it is very apparent that the accelerating conditions exert an ever diminishing influence the greater the distance between stops, and the lower the average speed for a given distance between stops. High rates of acceleration are the less desirable the greater the distance between stops. A large number of useful conclusions may be drawn from curves based on these and similar charts.

Fig. 26 gives curves of minimum rates of acceleration in miles per hour per second, for various average speeds, for one, two, four and eight-mile sections.

Fig. 27 shows the maximum speed corresponding to given schedule speeds for various accelerating rates for one, two, four and eight-mile sections.

In Fig. 28 are plotted S.T.D. curves for an acceleration of two miles per hour per second, and an average speed between stops of 60 miles per hour, for distances between stops of two, four, and eight miles. While for a stop every two miles an average speed of 60 miles per hour is only just possible by calculation at this rate of acceleration, and quite unattainable in practice, it becomes quite practicable, by means of electric traction, with one stop per eight miles. Fig. 29 gives corresponding curves for an acceleration of three miles per hour per second, which, as we shall see later, requires too great a consumption of energy during the accelerating period and too heavy an equipment to be commercially practicable.

Figs. 30 and 31 both relate to runs of four miles between stops at various speeds. In Fig. 30 the accelerating rate is one mile per hour per second, which, while low for electric traction, is high for steam traction: the accelerating rate in Fig. 31 is two miles per hour per second, which is readily exceeded with electric traction, but rarely or practically never attained by steam traction. Looked at with these facts in mind,

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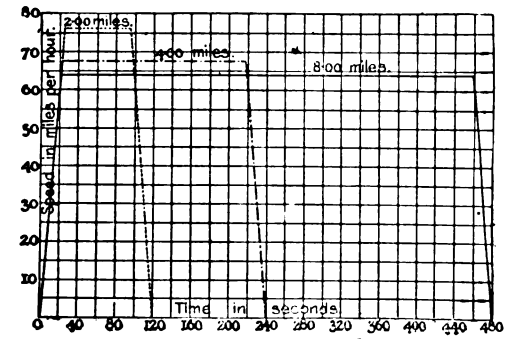
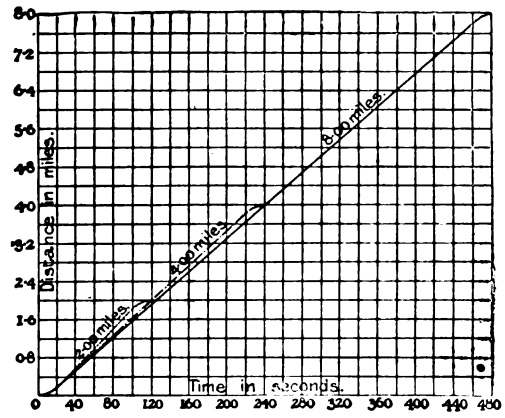
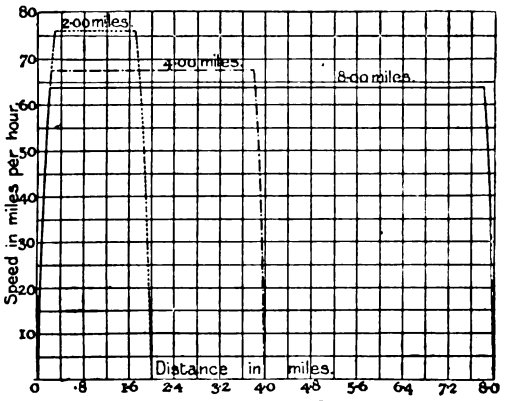
the two curves show at a glance the great increase in schedule speed rendered practicable



Speed-Time Curves.



Distance-Time Curves.



Speed-Distance Curves.

FIG. 29.—SPEED-DISTANCE-TIME CURVES FOR ACCELERATION OF 3 MILES PER HOUR PER SECOND, AND A MEAN SPEED OF 60 MILES PER HOUR BETWEEN STOPS.

by electric traction, even with such a comparatively long run as four miles between stops.

It is evident from the results of our investigation up to this stage that, altogether apart from the energy limitations, there are limitations to the practically attainable schedule speeds, which are the more narrow the shorter the run between successive stops. We shall now set forth a general method for investigating this matter in any case which may arise, always assuming that the acceleration equals the rate of retardation, that this rate is constant in each case, and that during the time intervening between acceleration and retardation constant speed is maintained.

We shall designate by—

A—the distance from start to stop.

x—the time of acceleration.

T—the total time from start to stop.

$V_{max.}$—the maximum speed between stops.

$V_{av.}$—the average speed between stops.

b—the acceleration.

B—the minimum acceleration to carry the train over the distance in a specified time T, the train being then abruptly brought to rest by an infinite braking effort.

Then $A = \frac{1}{2}BT^2$; $\therefore B = \frac{2A}{T^2}$.

If A and T are given, B can always be found by means of the curves in Fig. 32. Let $a = \frac{x}{T}$, *i.e.*, a is equal to the fraction of the total time, which is devoted to acceleration.

It is easy from these premises to derive the two following equations:—*

$$\frac{V_{max.}}{V_{av.}} = \frac{1}{1-a} \quad . \quad . \quad . \quad . \text{(I.)}$$

$$\frac{b}{B} = \frac{1}{2a(1-a)} \quad . \quad . \quad . \quad \text{(II.)}$$

---

* Equations I. and II. are derived as follows:—

$$A = V_{av.}\, T \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$A = 2\frac{V_{max.}}{2}x + V_{max.}(T - 2x) = V_{max.}(T - x) \quad (2)$$

Therefore from 1 and 2

$$\frac{V_{max.}}{V_{av.}} = \frac{T}{T-x} \quad . \quad . \quad . \quad . \quad (3)$$

$$V_{max.} = b \cdot x$$

$$b = \frac{V_{max.}}{x} = \frac{A}{x(T-x)} \quad . \quad . \quad . \quad (4)$$

$$B = \frac{2A}{T^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

from 4 and 5

$$\frac{b}{B} = \frac{T^2}{2x(T-x)} \quad . \quad . \quad . \quad . \quad (6)$$

but $a = \frac{x}{T}$;

$$\therefore \frac{V_{max.}}{V_{av.}} = \frac{1}{1-a} \quad . \quad . \quad . \quad . \quad \text{(I.)}$$

$$\frac{b}{B} = \frac{1}{2a(1-a)} \quad . \quad . \quad . \quad . \quad \text{(II.)}$$

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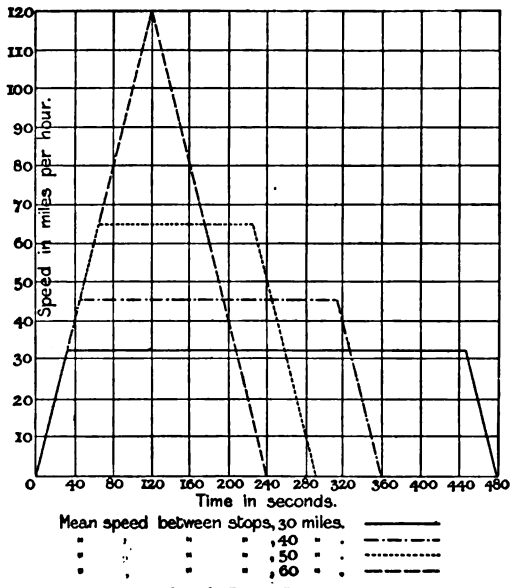
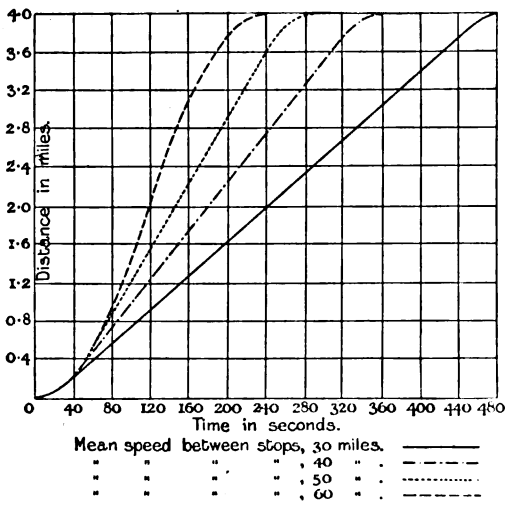
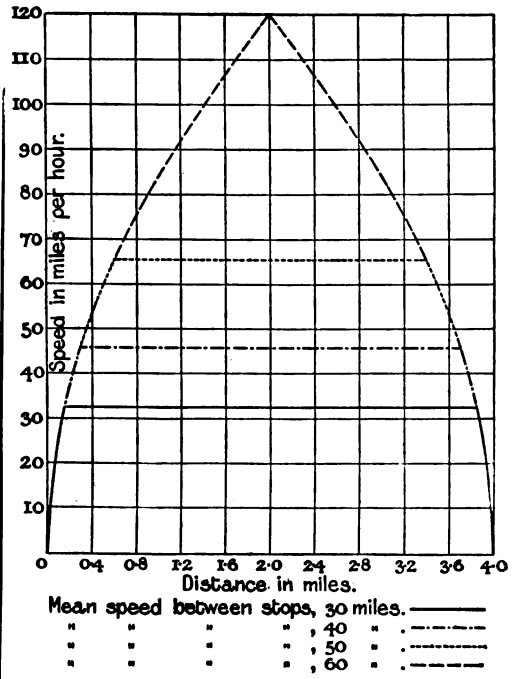


Speed-Time Curves.



Distance-Time Curves.



Speed-Distance Curves.

FIG. 30.—SPEED-DISTANCE-TIME CURVES FOR 4-MILE SECTION.

Acceleration, 1 mile per hour per second.

These two equations (I.) and (II.) are correct for all distances A, for all average speeds $V_{av.}$, and for all accelerating rates b. Their use may be simplified by plotting them in two curves (I.) and (II.) of Fig. 32, with values of a as abscissæ, and with the values

$$\frac{V_{max.}}{V_{av.}} \text{ and } \frac{b}{B}$$

respectively as ordinates.

The use of the curves in Fig. 32 may be best illustrated by means of an example:—Given a one-mile section (A = 5,280 feet), Schedule speed = 30 miles per hour;

$$\therefore T = 120 \text{ seconds.}$$

$$B = \frac{2A}{T^2} = \frac{2 \times 5{,}280}{120^2}$$

= 0·73 feet per second per second.

Let us ascertain the maximum speed ($V_{max.}$) and the minimum rate of acceleration (b), which will be necessary when x equals 18 seconds.

$$a = \frac{x}{T} = 0{\cdot}15,$$

i.e., the accelerating interval x, is 15 per cent. of the total time between stops T.

From curves I. and II. of Fig. 32, we find respectively that

$$\frac{V_{max.}}{V_{av.}} = 1{\cdot}20, \text{ and that } \frac{b}{B} = 3{\cdot}9;$$

$$\therefore V_{max.} = 1{\cdot}20 \times V_{av.} = 1{\cdot}20 \times 30 = 36{\cdot}0 \text{ miles per hour.}$$

$b = 3{\cdot}9 \times B = 3{\cdot}9 \times 0{\cdot}73 = 2{\cdot}84$ feet per second per second, or 1·93 miles per hour per second.

Suppose, on the other hand, that we want to maintain this same average speed, and that we wish to accelerate and retard at the rate of only 1·5 miles per hour per second.

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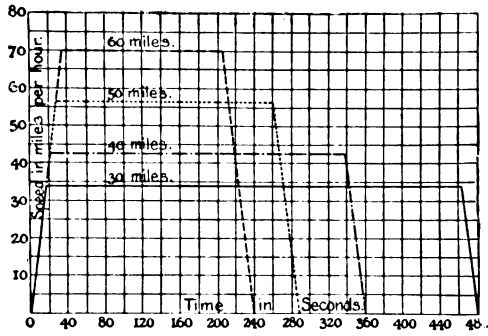
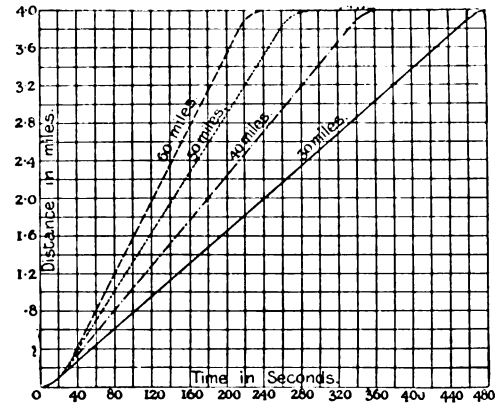
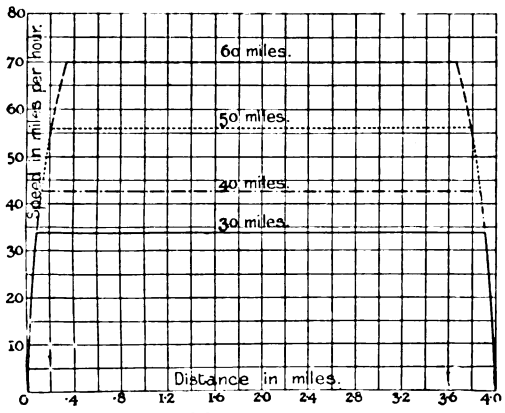


Speed-Time Curves.



Distance-Time Curves.



Speed-Distance Curves.

FIG. 31.—SPEED-DISTANCE-TIME CURVES FOR 4-MILE SECTION.
Acceleration, 2 miles per hour per second.

How many seconds will be required for acceleration?

B remains equal to 0·73 feet per second.

$b = 1·5 \times 1·47 = 2·20$ feet per second per second.

$$\frac{b}{B} = \frac{2·20}{0·73} = 3·02.$$

From curve II. of Fig. 32, we find

$$a \left(= \frac{x}{T} \right) = 0·21 ;$$

$\therefore x = 0·21\,T = 0·21 \times 120 = 25·2$ seconds.

The acceleration will thus occupy 25·2 seconds.

From curve I. of Fig. 32 we find that

$$\frac{V_{max.}}{V_{av.}} = 1·26 ;$$

$\therefore V_{max.} = 1·26 \times 30 = 37·8$ miles per hour is the maximum speed required.

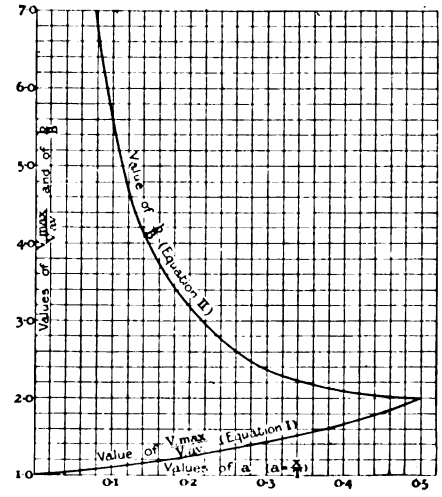


FIG. 32.—Curves showing values of $\frac{V_{max.}}{V_{min.}}$ and $\frac{b}{B}$, for various values of $a = \frac{x}{T}$.

(To be continued.)

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THE GEOMETRY OF THE SCREW PROPELLER.

PART II

By WILLIAM J. GOUDIE, B.Sc., A.M.I.Mech.E., Lecturer on Machine Design, Paisley Technical College.

THE principal items required for the moulding of a propeller blade are: the diameter; the pitch, whether uniform, radially or axially variable, or both; the shape of the expanded blade, and the widths and maximum thicknesses at various radii; the skew or set-back at the tip, if any.

A reference to the practical method of moulding the blade is here desirable, as the statement of the above information in a form most suitable for the use of the pattern-maker and moulder naturally depends on the "shop" conditions. The majority of students have few opportunities of studying this at first hand in the foundry, but they can to a certain extent overcome the drawback if, with the aid of a few simple tools and materials and the exercise of a little patience, they construct skeleton models of the various types of screw surfaces here described. For the moulding operation, consider the simplest case, that of the true screw. As already pointed out, the blade surface can be generated when a rigid line is rotated uniformly about an axis and caused to move parallel to the axis at a uniform rate; also the helix of uniform pitch, generated by the end of the line, when developed, is a straight line inclined at the screw angle to a plane at right angles to that of the axis.

Obviously then, if the development diagram or triangle, in the form of a templet, is fixed in the foundry floor, and the end of the line caused to travel down this while it is rotated (the line meanwhile being kept at a fixed angle to the axis), it will sweep out the true screw-surface in space. In the foundry apparatus the axis is replaced by a vertical spindle fixed in a foundation plate in the foundry pit, and the generating line is represented by the edge of a loam board.

A sliding sleeve with an arm attached to it is fitted on the spindle, and the loam board, with the lower or "striking" edge at any desired angle to the axis, is fixed on the arm.

This arrangement of sleeve arm and board is usually counterbalanced by chain weight and pulley, the pulley being pivoted on the top of the spindle, to allow the combination to be rotated.

The development diagram, usually called the "gable," consists of a wooden base and several uprights supporting a strip of wood inclined at the proper screw angle to the horizontal, and is weighted down on the brickwork base of the mould. This strip is curved to a radius several inches greater than the radius of the disc circle. The surface of the blade face is only a portion of a complete convolution of the screw, and hence only a portion of the development diagram is necessary for moulding purposes. The length of the gable arc represented by the wooden strip depends on the width of bed required; in ordinary practice it is usually not less than one-sixth the circumference. When getting out a propeller drawing, the most convenient base length for the development diagram at any radius is the radius $= \frac{\text{circumference}}{2\pi}$, and the proportional pitch height is therefore $\frac{\text{pitch}}{2\pi}$.

A rough brickwork structure is built up in the triangular space to be occupied by the bed, and the sloping surface is covered with loam. A space is left at the centre for the boss pattern, which may either be loam moulded or made of wood. This pattern usually has a V bead or circle round it at the middle of its depth. When it is placed in position in the mould, the inner end of the striking edge of the loam board (inclined at the desired angle if the blade is to have a setback) should, unless otherwise shown on the drawing, be set to this, and the gable adjusted till the centre point of its strip touches the striking edge at the tip end. When these adjustments have been made the surface of the face (which, it should be noted, lies downward) is swept out in the loam.

When this has been done, arcs are struck across the loam bed at different radii, usually by means of nail points screwed into the edge of the board. The board is again placed in the central position on the bed, and the radial centre line, which ought to be taken as the axis of reference for the blade

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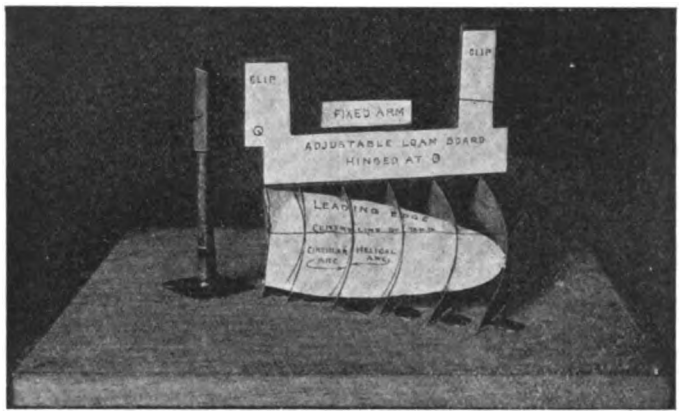

FIG. 9.

widths, is scribed along it. Let the student now partially reproduce the foundry conditions on a small scale by constructing the skeleton model shown in Fig. 9. It will help him to a clearer understanding of the geometry than the study of diagrams alone would do.

It can be easily and quickly constructed, and the cost of the materials is trifling. Procure a piece of board 12″ × 12″ × ¾″, a sheet of zinc, and a pair of strong scissors. For the purpose of construction, suppose the propeller has a diameter of 9′.0″, and a pitch of 9′.6″; that it is a true right-handed screw, and the blade is perpendicular to the axis.

Draw the axis Y_1Y_2 (Fig. 10) in the centre of the board, and X_1X_2 2¾″ from one edge; then complete the diagram to the dimensions given. Since the lines O*m* and O*n* are inclined, for convenience of construction, at 30° to the axis, the intercept on each arc between them will be ⅛th circumference; the common pitch height will therefore be ⅙ P = 19″. The intermediate radii are for guidance when the screw surface is being tested.

Next construct the combined development diagram (Fig. 11). Draw KL and KN at right angles, and set up the common pitch height KL = 19″. Measure the lengths of the arcs between O*m* and O*n* (Fig. 10) by bending a paper scale round them, and transfer the sizes to the base line KM (Fig. 11), setting off each from KL; then draw the diagonal lines, usually called the pitch lines.

Draw each triangle down on the zinc sheet and cut it out, leaving little triangular projections near ends of the base, as shown on the tip templet: centre-punch pinholes in these. Draw a vertical line through the

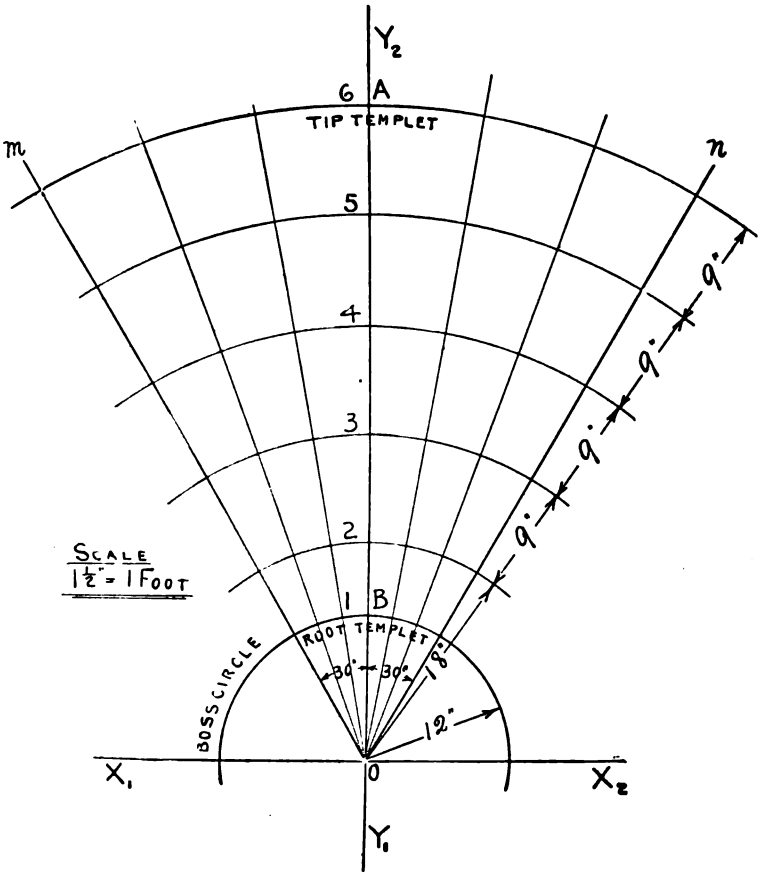

FIG. 10.

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centre point of each templet base, for guidance when setting to the axis Y_1Y_2, and nick the centre of each sloping edge with a file. Turn up the projections and bend each templet round its corresponding arc, then pin them down on the board with drawing pins.

The skeleton model of the true screw surface will now be complete. A black thread, stretched across the nicks on the templets, will represent the centre line of the loam bed, the nick at the root templet corresponding to the point on the centre circle of the boss pattern. This line will lie in the fore-and-aft plane, of which the reference axis Y_1Y_2 is the trace on the plane of the board or athwart-ship plane of the ship.

For the foundry spindle, obtain a piece of round wood about 6″ long and from $\frac{3}{8}$″ to $\frac{1}{2}$″ in diameter (a piece of cane will serve the purpose quite well), fix a brass or zinc base plate to it by means of a small screw nail, centre-punch four holes in this on the lines of the reference axes, and bend it till the spindle is plumb with the board; then pin down with drawing pins.

For the spindle sleeve and arm take a strip of zinc about $8\frac{1}{2}$″ long and $1\frac{1}{2}$″ in the body, and turn one end to form a hinge about 2″ deep, fitting easily on the spindle. Centre-punch a pinhole in this strip about $1\frac{1}{4}$″ from the centre of the hinge and $\frac{3}{8}$″ from the bottom edge. For the loam board take another piece of zinc, channel-shaped, $7″ \times 6″ \times 1\frac{1}{4}″$. Punch a pinhole about $\frac{3}{8}$″ from one end and $1\frac{3}{8}$″ from the bottom edge. Turn over the arms at each end, about 3″ and $3\frac{1}{2}$″ respectively at the pin and outer ends above the bottom edge, so as to form clips over the arm. Fix a drawing pin through the hole in the arm, then spring the clip end of the board to pass over this till the pin enters the hole in the board and forms a pin joint; the clip will keep the pin in position. This simple and easily constructed combination of fixed arm and shifting board can now be used for testing any of the skeleton screw surfaces under review. For this case, where the blade is perpendicular to the axis, clamp the board with the

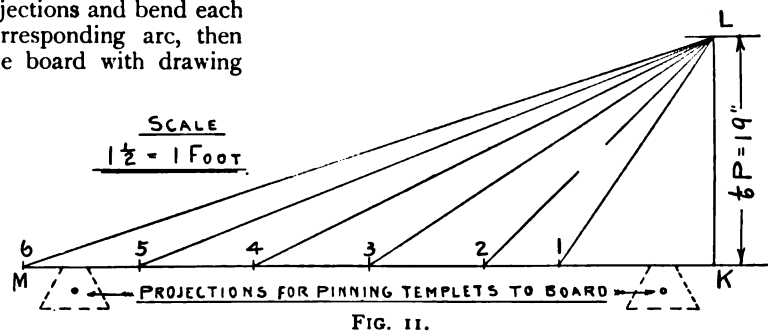

FIG. 11.

lower edge parallel to the base of the model, by tying a thread tightly round the outer clip, as shown in Fig. 9, then sweep it up the skeleton surface and note if the edge remains in contact with all the templets, in every radial position. The surface can also be tested by placing a straight-edge across the templets, in line with the guide radials on the model base, and trying its parallelism to the base by means of a surface gauge.

Suppose now that the blade is to be given a set-back. In practice the slope or inclination to the athwartship plane averages about 10°, or the set-back at the tip runs about 1″ per foot diameter of propeller.

Raise the sleeve till the edge of the loam board, resting at the outer end on the centre nick of the tip templet, has the desired slope, to the model base, or what is the same thing to the thread centre line of the perpendicular surface, then clamp the outer end as before. Suppose, in this position, that the root end of the board is 7″ above the centre point of the root templet, the distances

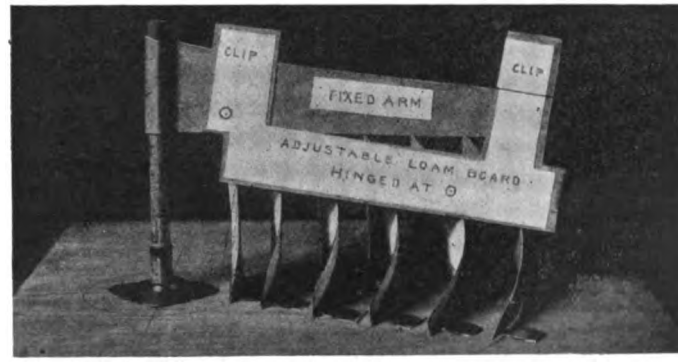

FIG. 12.

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from the board edge to the other templets will be :—

	Root					Tip
No. . .	1	2	3	4	5	6
Height .	7″	6″	4½″	3″	1½″	0

Draw the templets out again on stiff drawing paper; but instead of cutting each along the base, cut it along a line parallel to the base, and distant from it by the amount that the board edge is above the templet edge. Draw the vertical centre lines through the centre points of the bases and nick the edges as before; then bend each raised templet round and paste it inside the zinc one. The paper edges will now give the skeleton surface of the set-back blade. Sweep the inclined board up this, as before, and note that at every radial position it remains in contact with all the templet edges. The whole surface has now an inclination aft; but the screw angle at each radius is the same as that for the perpendicular blade, since each templet has simply been raised bodily, to touch the generating line. Fig. 12 shows the model of the surface thus modified for set-back, with the loam board in the centre position on the bed.

If the blade is to have a radially increasing pitch, the end B of the loam board has to move at a slower rate than A, and it follows that the inclination of the board edge to the axis will vary at every radial position. The board must therefore be guided at B as well as at A, and at the same time be able to swivel at B, so that a root templet is necessary. In the foundry arrangement some form of pin joint, such as illustrated on the model, is sometimes used. A simple plan is to provide the board with a forked end, which can fit on the spindle and at the same time allow the board to cant and adjust itself to the root and tip templets.

Suppose that the blade is to have a pitch radially increasing from 8′.6″ at the root to 10′.6″ at the tip, and to be at right angles to the axis. This is a larger variation than would be given in practice; it is chosen here to make the illustration clearer. For the construction of the set of templets for this case, refer to Fig. 13. Draw A B = 3′.6″; at A set up $A A_1 = \frac{1}{6} P_t = \frac{\text{pitch at tip}}{6} = 21''$ and at B, $B B_1 = \frac{1}{6} P_r = \frac{\text{pitch at root}}{6} = 17''$: join A_1 and B_1. Erect ordinates at each radial position, and where they intersect $A_1 B_1$ project back on to $A A_1$. Set off the arc lengths from $A A_1$ as before, and complete the development triangles. If the templets are cut out to these sizes and pinned down as before, the edge line of the loam board, when placed on the centre of the bed, will be higher at the tip than at the root end, and

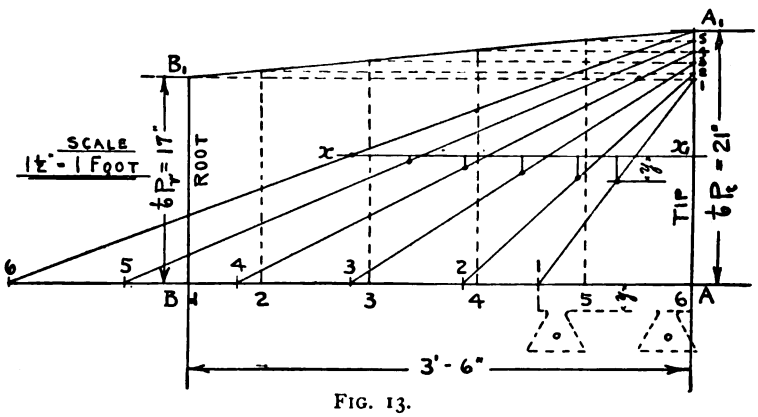

FIG. 13.

the surface, swept up to the extreme templets, would have a slight inclination forward. To obtain the perpendicular blade, therefore, the root templet must be raised till it touches the horizontal board edge, when it rests on the tip templet. The other templets must be correspondingly raised. Through the centre point x (Fig. 13) of the edge of the tip or No. 6 templet draw the horizontal $x x_1$. The distance from this line to the centre point of any templet edge will give the amount the templet has to be raised. The templet must therefore be cut along a line parallel to and at this distance from the base, as indicated by the dotted lines on the root templet. When these modified templets have been pinned on the board, sweep up the surface with the loam board free at the outer end, and note if its edge makes contact with all the templets, at each radial position, while it lies on the root and tip ones.

If the blade is to have a set-back, as in the previous case, obviously it is only necessary to shift the base line of each templet the proportionate distance given for the true screw blade, and cut it along this line.

(To be continued.)

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THE ELEMENTS OF CHEMICAL ENGINEERING.

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By J. GROSSMANN, M.A., Ph.D., F.I.C., Chemical Engineer and Consulting Chemist, Manchester.

Introduction.

THE student who has gone through a course of study in analytical and theoretical chemistry often finds great difficulty in adapting himself to the altered circumstances which regulate chemical work when carried out on a large scale, and, therefore, fails to grasp the principles of chemical technology. It may be laid down as a fundamental difference between theoretical and commercial work that, whilst the question of cost does not enter into theoretical work, it is the fundamental basis of all commercial work. Thus, if it were necessary to prepare nitrate of ammonia in the laboratory in an extremely pure state, the cost of materials, the amount of time spent, the labour, the breakage of vessels, cost of heating, evaporating and drying, the initial cost of the apparatus and final cost of packing in bottles or jars, would be of no consequence, so long as the object in view is attained. But if the problem were put to a student to make nitrate of ammonia in the cheapest manner on a large scale, the conditions under which the work would have to be carried out would be fundamentally different. He would have to choose, amongst a number of possible processes, the one which, when all the above conditions are taken into account, enables the manufacturer to produce the article required in the cheapest manner, not only as regards the cost of the raw materials, but also as regards the initial cost of the plant, and the consequent interest on capital expended, the depreciation of the plant, the labour, the fuel, and the cost of packing, as well as incidental charges in the management of the works and office.

But apart from these questions there is a great difficulty in understanding the apparatus which is used on a large manufacturing scale. Without any intermediate stage the student must at once accommodate his ideas, which have been trained by using extremely small quantities, to the use of extremely large quantities; and whilst he would be quite capable of understanding how to mix nitric acid and ammonia to produce nitrate of ammonia, in a beaker or a basin, he would be totally at sea if he were asked to construct the apparatus necessary to carry this operation out on a large scale. I have endeavoured, in the next few chapters, to make the transition from the small laboratory scale to the large manufacturing scale, not abrupt, as it is now to the student, but gradual; and for this purpose I have tried, where possible, to represent the operations which are carried out on a large scale, as almost natural evolutions arising from the work with the laboratory apparatus to which the student has been accustomed.

The Technical Evolution of the Beaker.

One of the commonest appliances used in the laboratory is the beaker, made of glass or porcelain, and it will be instructive to follow its evolution in working on a large scale.

Ordinary laboratory beakers are made in different sizes, to hold any quantity from an ounce and less to half a gallon and more. They are applied for different purposes; for storing or mixing liquors, for dissolving solids in liquids either in the cold or by heat; and in some cases, though not often, for boiling down, concentrating, and crystallising. For the latter purpose porcelain basins are preferred. As the uses of beakers and basins are almost identical, we may, where convenient, include the evolution of the basin in that of the beaker.

One of the simplest operations is that of mixing two liquids. Suppose we had to make 100 centimeters or more of a solution of sulphuric acid containing approximately one part of H_2SO_4 to ten of water. We should measure 100 cubic centimeters of water into a beaker or dish, and add slowly about 10 cubic centimeters of H_2SO_4, stirring all the time with a glass rod. Suppose now that we have to prepare the same mixture on a large scale, say 100 gallons at a time. The first question to decide would be, what material should the mixing vessel be made of? We know that glass would not do; earthenware would stand the acid, but would be liable to breakage; lead would stand cold acid of that

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dilution well, and would not be liable to breakage; therefore lead would be the best material for the purpose, and in order to save expense, the vessel would be made of comparatively thin lead, surrounded with a wood casing. The shape of the vessel would be determined, for the only practicable shape for casing would be a figure in straight lines; *i.e.*, either a cube, or an oblong box. As regards the size, it is clear that as we have to mix the acid and water, we must allow for splashing, and, therefore, make the box about 25 per cent. larger; that is, to hold at least 125 gallons. Now 125 gallons are equal to 20 cubic feet; we might, therefore, have it either—

2′ 0″ × 2′ 6″ × 4′ 0″ high;
or, 2′ 0″ × 2′ 0″ × 5′ 0″ high;
or, 2′ 0″ × 3′ 6″ × 3′ 0″ high;
or, 2′ 0″ × 3′ 0″ × 3′ 6″ high;

whichever dimensions may appear to strike our fancy, or to be the most suitable for other purposes.

The mixing of the acid could be done with a wooden paddle, which might be covered with lead; and as, in using the paddle, it might knock with greater force against the bottom of the vessel than against the sides, it will be advisable to have the bottom of the vessel made of stronger lead than the sides. Considerable latitude is permissible in choosing the thickness of the lead; its choice depends upon the number of years for which one requires the vessel to stand wear and tear. The sides might be made of lead 0·068 inches thick, the bottom 0·119 inches thick.

In practice it is not usual to express lead measurements in that way, the custom being to take the weight of sheet lead per square foot, thus lead 0·068 inches thick is termed four-pound lead, and lead 0·119 inches thick seven-pound lead. Therefore, in this case, the way to express the quality of lead which should be used would be four-pound lead for the sides and seven-pound lead for the bottom. The joints where the lead sheets meet in making the box would have to be "burned" by the hydrogen flame, as is the case in all chemical work; for it is clear that solder could not be used for that purpose. The top should overlap the casing.

We shall now suppose that instead of our being required to mix weak vitriol, the problem put to us is to make a cold ten per cent. solution of soda-ash. In this case, if only a quantity of 100 cubic centimeters were required, one would measure 100 cubic centimeters of water into a beaker or dish, and weigh into it ten grams of soda-ash, and stir up until it is all dissolved; this would take considerably longer to stir than the mixing of two liquids. Now, if this operation is extended, and if it should be necessary to prepare a solution of this kind regularly on a large scale, say 200 gallons at a time, the problem is, what vessel would be most suitable for the purpose. First of all, what is the material which could be used for the vessel employed? As soda-ash does not attack iron, and iron, after all, is the cheapest material which can be used on a large scale, it is evident that the vessel should be made

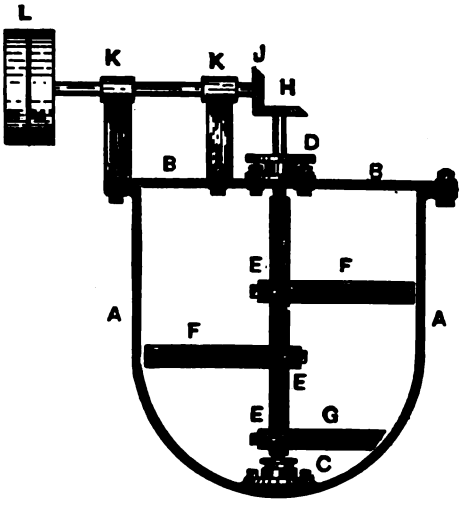

FIG. 1.—SECTIONAL ELEVATION OF IRON VESSEL AND STIRRERS, FOR DISSOLVING SODA-ASH IN WATER.

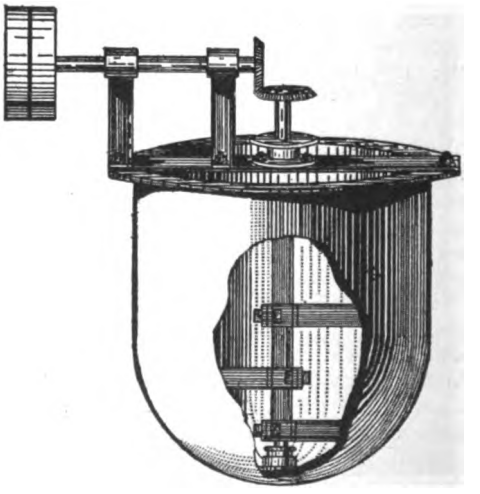

FIG. 2.—PERSPECTIVE VIEW OF VESSEL REPRESENTED IN SECTION IN FIG. 1.

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of iron. Cast or wrought iron could be used: as a rule, however, cast iron is cheaper than wrought iron, and also offers the advantage of having a smoother surface free from joints. In this particular instance, however, it might be as cheap, and perhaps cheaper, to have an ordinary wrought iron water cistern, 4 ft. × 3 ft. × 3 ft. 3 in., and use it for the purpose. Two hundred gallons of water might be put into this box, and 20 lbs. of soda-ash weighed and gradually put into it, the whole being stirred up with an iron or wooden paddle until dissolved. But it will be found that the labour on this would be considerable, and it would, therefore, be advisable to construct an arrangement such that the stirring could be done automatically by a machine. The simplest form of a stirrer of this kind would be a centre shaft with revolving cross-pieces.

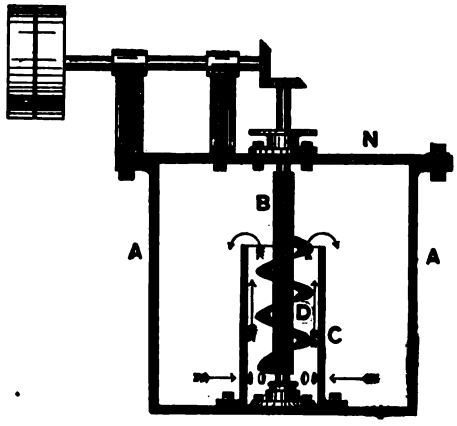

FIG. 3.—SECTIONAL ELEVATION OF VESSEL FOR MIXING LIQUIDS BY MEANS OF AN ARCHIMEDIAN SCREW.

It is clear that in this case the vessel would have to be of cylindrical shape, which might be a cylinder with a flat bottom. Most iron vessels are made with a round bottom, and in this case it would be an advantage to have a round bottom, so that none of the soda-ash could lodge in the crevices which are between the sides and the bottom of the cylindrical vessel. We should, therefore, construct a vessel similar to the shape of a wash kitchen boiler, only larger, with a flange on which we should screw a plate to hold the gearing.

Figs. 1 and 2 show a complete arrangement of such an apparatus: Fig. 1 in section, and Fig. 2 in perspective. A is a cast iron pot with flange; an iron plate B, about six inches wide, is bolted on to the flange; through the middle of this plate goes a shaft which rests on the bottom in a footstep C, and passes through the collar D, which is fixed on plate B. The shaft is best made square, and only rounded at the top and bottom part so as to revolve in C and D. F and G are stirrers which are either clamped or fastened through slots in E, at right angles to the shaft. H and J are spur wheels which change the vertical motion into a horizontal one. K, K are the axle bearers, while L, L are fast and loose pulleys, which are worked from shafting by means of an endless belt.

There are cases when it is not convenient to employ this kind of stirrer, which moreover, is not always very trustworthy, as in revolving in large quantities of liquids, particularly those of a viscous nature, the liquor is apt to go round with the agitator without properly mixing. In such cases, and where it is

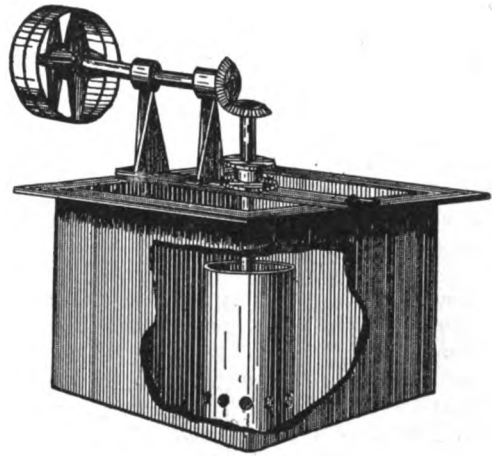

FIG. 4.—PERSPECTIVE VIEW OF VESSEL REPRESENTED IN SECTION IN FIG. 3.

desirable to apply a rectangular vessel, another form of agitation may be used, based on the working of a ship's screw. Figs. 3 and 4 show such an arrangement.

A is a square tank. B is a vertical shaft which moves in footstep and collar, as in Fig. 2, the latter being fastened on a plate N. D is an Archimedian screw surrounded by pipe C, which is fastened to the bottom of the tank, and at the bottom is perforated, so that the screw can draw the liquor from the bottom of the tank, and pump it up in the direction of the arrows, and deliver it at the outlet of the pipe. In this way every part of the liquor is pumped through the pipe and made to mix thoroughly.

The next step that we have to consider is the conditions under which these operations would have to be carried on if it were necessary

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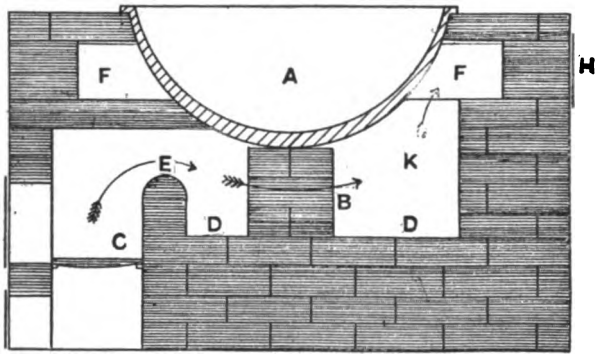

FIG. 5.—VERTICAL SECTION OF WHEEL FLUE.

to heat the liquid while it is being mixed. Three ways of doing this are open to us. The first way is by simply blowing live steam into the liquid: in this case the volume of the liquid will become larger as the steam condenses in it; where this does not matter, it is the simplest way of heating the liquid. The next arrangement would be to pass steam through a coil contained in the tank, and thus heat the liquid. The third way would be to heat the pot by a coal or coke fire. Going back to Fig. 2, it can be easily seen that if the pot were to be heated by open steam, the arms of the agitator would have to be cut shorter, so as to allow of the steam pipe going down at the side of the pot; if they were brought near to the sides of the pot, they would knock against the pipe at each revolution. Of course the pipe could be brought along the outside, and taken in at the bottom of the pot through a hole bored through, but this would be an awkward arrangement, as with any differences of temperature the liquor might be drawn back into the steam pipe. In heating by means of closed steam, an agitating arrangement, as described in Fig. 2, would be awkward unless the coil were specially made to fit close to the sides of the pot, and such a coil would be expensive. It will now be seen why it is sometimes advisable to have a rectangular tank for purposes of this kind, and why the agitating arrangement, as described in Fig. 3, is sometimes preferable. In that arrangement it would be easy to use either a steam pipe or a steam coil. The steam coil could be placed at the bottom, and both the inlet of steam and the outlet for the condense could be regulated by taps.

If the pot is to be heated by open fire, some new principles which do not apply to laboratory work will have to be considered. When we heat a beaker in the laboratory from a gas jet, the beaker is simply placed on the wire gauze net, and the flame applied underneath. It is natural that in this way a great deal of the heat is lost by radiation; and on a large scale, where it is necessary to consider the question of economy very carefully, it would not be advisable to heat the pot in such a manner as to apply the heat only to the bottom of the vessel. For this reason, it will be necessary to construct a heating arrangement in such a way that the gases evolved from the combustion of coal are taken round the pot, so as to travel over and cover a greater surface of the pot. Such arrangements may be arrived at in different ways; one of the simplest and most efficient is that of the wheel flue, which is shown in Figs. 5 and 6.

Fig. 5 represents a vertical section, and Fig. 6 a plan of the arrangement. A is a cast-iron pot which rests on a solid brick pillar B. The fire-grate C is separated from the bed D of the furnace by the bridge E, which also prevents the fuel from being carried over. The gaseous products of combustion pass over the bridge, under the pot, then upwards through the flue K into the flue F, where they are taken round in an anti-

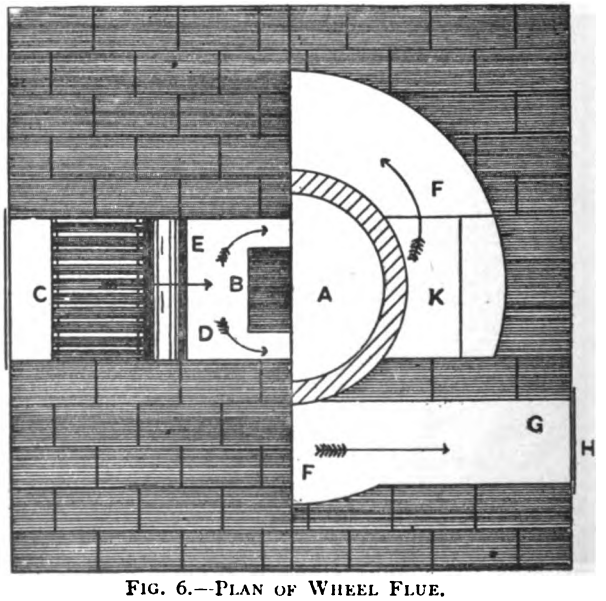

FIG. 6.—PLAN OF WHEEL FLUE.

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clockwise direction to G, into a flue which conveys them to the chimney. The chimney draught is controlled by a damper H. Even with an arrangement like the above, a great deal of the available heat is still lost. It is in many cases more economical to put two or three furnaces together, working them from one fireplace under the front pot. The waste gases in that case pass from the exit flue of the first pot, which otherwise lead into the chimney under the second pot; they are made to circulate round the second pot, from there to the third pot, and from this into the chimney. In arrangements of this kind cold liquor is fed into the coldest pot (that is the third pot), is syphoned automatically into the second pot, and from there into the first pot, which will always contain the most concentrated liquor.

(To be continued.)

THE CALORIFIC VALUE OF CARBON.

By HORACE ALLEN.

THE importance of a more correct figure for the calorific value of carbon will be recognised by all engaged in the study of combustion. The failures of various investigators to obtain concordant results are no doubt due to the impurities and physical condition of the substances operated on.

Carbonic acid gas is the result of complete oxidation of carbon, in whatever physical form the carbon may have originally been; thus it follows that if a determination of the heat necessary to decompose a certain weight of this gas can be determined, then a definite heat value can be given to carbon. The writer has endeavoured to arrive at an approximate figure as follows:—

Assuming the temperature of combination to be 1,000° F.

Carbon, 1·00 lb. × 0·2 sp. ht. × 1,000° F.	200
Oxygen, 2·66 lb. × 0·2182 sp. ht. × 1,000° F.	580
Latent heat	780
Net total heat	14,544
Gross total heat, in B.Th.U's. per lb. of carbon	15,324

If any reader of TECHNICS can solve the problem in the manner suggested, he would be conferring a great boon to students of combustion.

A WEDGE FOR HAMMER AND TOOL HANDLES.

THE securing of the heads of hammers and other similar tools is a matter of practical importance; a simple contrivance for this purpose, patented by Willis, and sold by C. Lindley and Co., Ltd., of Englefield Road, N., should prove very useful to mechanics. A

malleable iron wedge is provided with a short transverse slot at its thicker end; this wedge is driven into the shaft of the hammer, and a staple is then driven in astride the slot, its ends opening out as shown in the accompanying illustration, thus preventing the wedge from coming loose.

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ELECTRIC WAVES.

PART V.—RESONANCE.

By J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London.

REFERENCE has already been made to the fact that every electric circuit has a natural period of oscillation, in which its electric charge vibrates if disturbed and left to itself.

We know well that if a weight hanging at the end of a spiral spring is given an upward blow, and then left to vibrate, it bobs up and down executing oscillations which gradually die away owing to the friction of the air. These oscillations are very nearly isochronous, that is, each complete oscillation up and down occupies the same time, whether the oscillations are large or small in amplitude. This periodic time is called the *natural free period* of the vibrating system, and is determined by the inertia of the mass and the elasticity of the spring. Unless both these qualities are present, there can be no vibration at all. The simplest experiment with such an oscillating mass suffices to convince us that we can accumulate vibrations

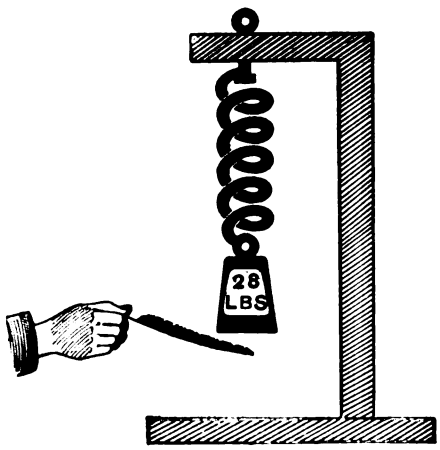

FIG. 1.—TO ILLUSTRATE THE CUMULATIVE EFFECT OF SMALL IMPULSES, WHEN PROPERLY TIMED, ON A SYSTEM FREE TO OSCILLATE.

of very extensive range by administering to the mass or bob very small blows, provided that we give these blows exactly at the right interval. Thus, suppose we hang up a tolerably heavy block of metal (say a 28-lb. weight), by a very strong spiral spring (see Fig. 1), then we have a body capable of oscillation in a definite time. Take a feather and give the weight a few irregular pats on its underneath side in an upward direction: not the slightest motion of the heavy weight will result. Then press down the heavy weight with the hand and let it go: it will bob slowly up and down; count the number of these vibrations per minute, and then bring the weight again to rest. Suppose, for instance, that the number of swings per minute is fifteen. Next, begin again to administer slight blows to the weight with the feather; this time, however, take care to give them at the rate of fifteen per minute perfectly uniformly. If they are properly timed, it will be found

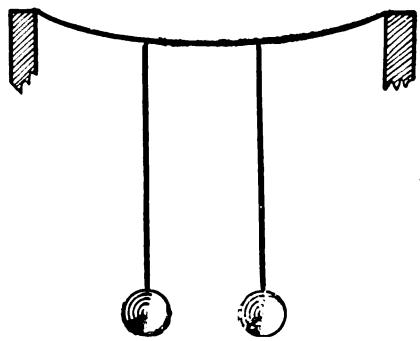

FIG. 2.—TO ILLUSTRATE THE TRANSFERENCE OF ENERGY FROM ONE PENDULUM TO ANOTHER OF THE SAME NATURAL FREE PERIOD.

that shortly these very gentle touches with the feather are able to set the massive weight in vigorous vibration. Here we have an instance of the effect of properly timed impulses upon a system capable of oscillation, and the manner in which the most gentle impulses may accumulate dangerous vibration in such a system. Plenty of illustrations of this principle will occur to everyone. An instructive one is to suspend two equal pendulums, formed by attaching metal balls to strings or wires, from a cross wire (see Fig. 2). If one pendulum is set in vibration it gradually sets the other one swinging, and after a time the first transfers the whole of its energy to the second, so that the pendulum originally at rest is vibrating and the one originally set vibrating is at rest. This experiment, however, will not succeed if the pendulums are of unequal lengths.

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In the case of a simple pendulum the time of one complete vibration is given by the formula

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l is the length and g the acceleration of gravity. If the pendulum is of irregular shape then the general formula applies, *viz.*:—

$$T = 2\pi\sqrt{\frac{I}{K}}$$

where I is the moment of inertia of the vibrating system, and K is the restoring torque per unit angle when that angle is small.

In the case of an electrical system we have seen that the inductance (L) of the circuit corresponds to the inertia (I) of the mechanical system, and the capacity corresponds to the pliability. Hence the mathematical expression for the time of one electrical vibration of a system possessing capacity and inductance is—

$$T = 2\pi\sqrt{\frac{L}{(1/C)}} = 2\pi\sqrt{LC}.$$

Returning to the consideration of the establishment of oscillations by very small impulses, we have numerous illustrations of this action in acoustics. If we hold a suitable tuning-fork in vibration over a tall glass jar and fill up the jar partly with water, it is found that, corresponding to a certain length of the column of air in the jar, the sound of the tuning-fork waxes much louder. This happens when the length is so adjusted that the natural free period of oscillation of the column of air agrees with that of the tuning-fork.

The above described experiment is the simplest illustration of the operation of *resonance* in acoustics; and from a similarity to it, certain electrical phenomena are spoken of as due to *electric resonance*. An illustration of this last effect is as follows:—

A long wire W, W (see Fig. 3), is coiled in very open turns round a wooden cylinder. One end of this wire is connected to the inner coating of a large insulated Leyden jar L. The outer coating of this jar is connected to one of the secondary terminals of an induction coil I, and the other terminal is connected to some movable contact *a* on the long spiral wire (see Fig. 3). The secondary terminals of the induction coil are provided with spark balls S, which are placed within a few millimeters of each other. When the coil is set in action oscillatory sparks pass between these balls, and an oscillatory discharge takes place through the section of the long spiral wire included between the contact and the jar terminal. If the position of this contact is varied, it is generally possible to find such a position that a powerful electric brush discharge will suddenly make its appearance at the upper or free end F of the long spiral wire. This indicates that the electric potential at this point is very high. If we take a metal rod and hold it near to the spiral at various points, we shall find that the length of spark we can draw from it varies and diminishes as we go down the spiral away from the free end. Such an arrangement is known as a *resonant spiral*, and is employed under the name of an *Oudin resonator* for the production of the high frequency electric discharges now much used in medical electrical treatment.

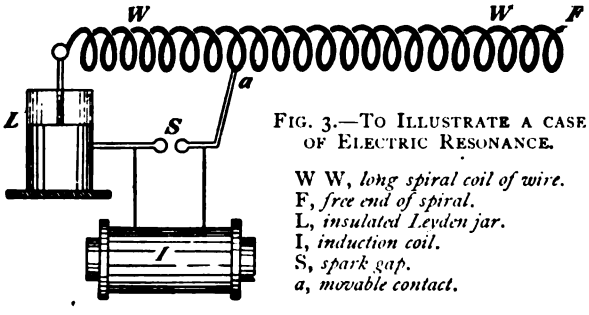

FIG. 3.—TO ILLUSTRATE A CASE OF ELECTRIC RESONANCE.

W W, *long spiral coil of wire.*
F, *free end of spiral.*
L, *insulated Leyden jar.*
I, *induction coil.*
S, *spark gap.*
a, *movable contact.*

The explanation of the action is as follows: When electrical oscillations are set up by the jar discharge in the left-hand section of the wire, the adjacent point of the free section of the wire is subjected to rapid alternation of potential. These are propagated along the free wire at a rate which depends upon its capacity with respect to the earth, and its inductance. When the potential wave arrives at the free end of the wire it is reflected, just as an air wave is reflected from the closed end of a pipe up which it travels. If the length of the wire is so adjusted that the time required for the electric potential wave to travel up to the end and back again is exactly equal to the time of one semi-complete electric oscillation of the jar circuit, then each oscillation is timed so as to re-enforce its predecessor in effect. The process is exactly analogous to the experiment with the tall glass jar and tuning fork. The ærial impulses or waves set up by the tuning fork travel up the tube and back again in the time of one semi-complete oscillation of the fork; hence each one adds to the effect of the one before, and air vibrations of

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large amplitude are soon excited, indicated by the increased loudness of the sound.

The electrical experiment may also be performed the other way round. The vibrations in the open or free circuit may be made to set up others in a resonant, tuned, or syntonic, closed circuit.

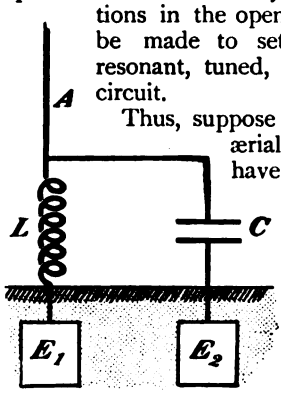

FIG. 4.—SIMPLE FORM OF SYNTONIC RECEIVING CIRCUIT.

A, *aerial or antenna.*
L, *coil possessing inductance.*
C, *condenser.*
E_1, E_2, *earth connections.*

Thus, suppose a vertical wire or ærial A (see Fig. 4) to have its lower extremity in contact with the earth, and some point near the lower end connected to the earth through a condenser.

Let electric waves passing through space, with their electric force-components perpendicular to the earth's surface, fall on the wire. Then, as already explained, these incident waves will excite electric oscillations in the wire. Suppose the time-period of the ærial to be adjusted by the insertion of an inductance coil L (see Fig. 4) so as to agree with the periodicity of the waves; also let the condenser C (see Fig. 4) have its capacity so adjusted that the time-period of the condenser and inductance agrees with that of the ærial A and its associated inductance. Then the incident electric waves, even though feeble, will create strong oscillations in the condenser circuit. This is a simple illustration of a syntonic receiving circuit in connection with wireless telegraphy. It is well, however, to explain here that this does not imply that powerful waves of any period will not affect the closed circuit, but only that, for sustained trains of somewhat feeble waves, those of the co-resonant period produce more marked effects than others.

A similar and very interesting experiment illustrating electric resonance can be shown as follows, and constitutes a very telling lecture experiment.*

Two spirals of silk-covered copper wire, A and B (see Fig. 5), are prepared by winding it in one layer of closely adjacent turns on two glass tubes. Those used by the author have the following dimensions:—

Spiral A.

Length of spiral or helix	= 20·5 cms.
Diameter of helix . .	= 3·3 cms.
Number of turns . . .	= 513.
Inductance . .	= 1,379,800 cms.

Spiral B.

Length of spiral or helix	= 20·4 cms.
Diameter of helix . .	= 3·5 cms.
Number of turns . . .	= 813.
Inductance . .	= 3,918,200 cms.

* Apparatus for this purpose has been designed by G. Seibt, and is made by Messrs. Ernecke, of Berlin.

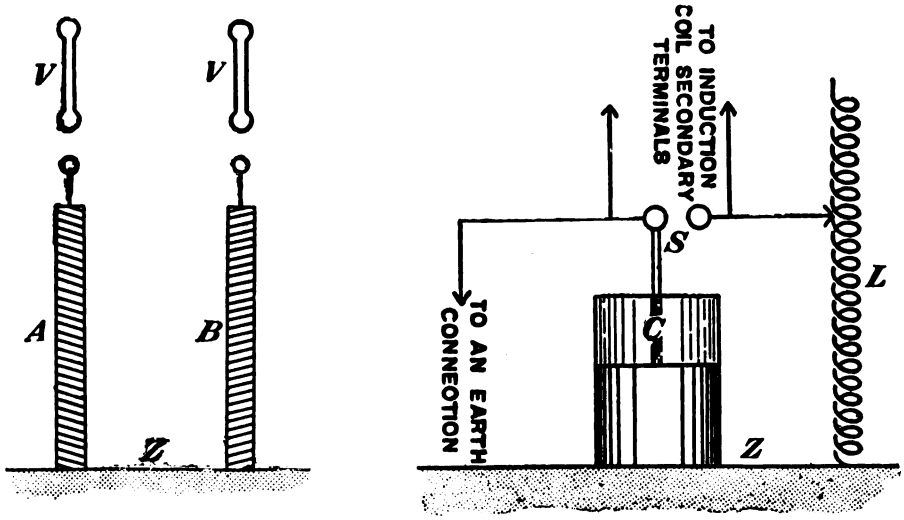

FIG. 5.—TO ILLUSTRATE AN EXPERIMENT ON ELECTRIC RESONANCE

A, B, *long spiral coils.*
V, V, *vacuum tubes.*
Z, Z, *sheet of zinc.*
S, *spark gap.*
C, *Leyden jar.*
L, *adjustable inductance coil.*

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As the capacity of each helix, when in a vertical position with respect to the earth, is the same, and since the inductance of one is nearly three times that of the other, their natural electrical free periodic times are in the ratio of 1 to $\sqrt{3}$, the one with greater inductance having the longer time-period.

These spirals are carried on wooden stands with metal feet; the lower end of each spiral of wire is connected to the corresponding foot, whilst the upper end terminates in a small metal ball over which is suspended a vacuum tube V (see Fig. 5). It is well to select two vacuum tubes filled with different gases, one glowing red and the other blue, under the action of the high frequency discharge.

The spirals are placed upon a strip of zinc Z laid upon a dry table, and one end of this strip is connected to an oscillating circuit consisting of a spark gap S, a Leyden jar C, and an adjustable inductance coil L. One point on this jar circuit must be connected to the earth as indicated.

On setting the oscillating circuit of the jars in operation by means of an induction coil, the zinc strip will be the seat of oscillations of potential which set up electrical vibrations in the spirals, provided the time-period of the impulses agrees nearly with that of the spirals. Accordingly, by varying the inductance in series with the Leyden jars, we can set up strong oscillations in one or other of the spirals A or B, and cause the vacuum tube V, held over its free upper extremity, to glow brilliantly.

If the spiral or helix in which we set up oscillations is of considerable length, then we can set up in it stationary oscillations which correspond to the higher harmonics, and not to the fundamental. It is well known to musicians that if an organ pipe is over-blown (or blown strongly), it yields a note of higher pitch than the fundamental; and with care a whole series of harmonics can be produced having oscillation frequencies respectively two, three, four, five or more times that of the fundamental note.

If an insulated wire is wound in one layer in closely adjacent turns on an ebonite rod, the diameter of which is, say, two inches or five centimeters, and the length eighty inches or 200 centimeters, then such a spiral will exhibit very well the phenomena above mentioned. The spiral should be supported in a horizontal position on insulating stands, and one end should be connected to an oscillating circuit consisting of a condenser or Leyden jar, a spark gap, and a variable inductance.

If the inductance is adjusted, we can succeed in setting up on the spiral a stationary electric oscillation which is the fundamental, and causes a powerful electric brush discharge to appear at the open end of the helix.

The following details may be of assistance to any one desiring to repeat the experiment.

The helix of wire consists of No. 32 S.W.G. double silk-covered wire wound on a rod four centimeters in diameter in 5,000 turns and occupying 200 centimeters in length. The oscillating circuit consists of two Leyden jars each about 0·0014 microfarad in capacity, which can be joined in parallel, giving a capacity of 0·0028 microfarad. The inductance consists of a spiral of variable length giving inductances up to 200,000 centimeters. If we now make the capacity in the jar circuit 0·0028 microfarad, and the inductance 102,600 centimeters, the frequency of that circuit will be 300,000 or $0{\cdot}3 \times 10^6$; it will be found that, if the outer coatings of the jars are earthed and the inner coatings connected to the spiral described above, a glow discharge will take place from all parts of the spiral, decreasing in intensity from the open or free end. At the open end we shall be able to draw off sparks six inches long, but at the end nearest the jars, hardly any spark at all. Under these conditions the time taken for the potential wave to travel up and down the helix is equal to a semi-complete period of the exciting circuit. Hence the wave travels 400 centimeters in 1/600,000 of a second: in other words, the velocity is 240 million centimeters per second. The correctness of this conclusion can be checked in two ways. The velocity with which the wave travels along the spiral can be shown to be numerically equal to $1/\sqrt{lc}$ where l is the inductance of the spiral, and c is the capacity—both per unit of length and in electromagnetic units.

In the case of the above-mentioned spiral these values are

$$c = 0{\cdot}00000018 \text{ microfarad}$$
$$= 18/10^{23} \text{ C.G.S. units.}$$

$l = 100{,}000$ centimeters $= 10^5$ C.G.S. units.

Hence $1/\sqrt{lc} = 236 \times 10^6$ centimeters per second: this is in remarkably close agreement with the velocity deduced previously from the capacity and inductance required in the jar circuit in order to produce the fundamental oscillation.

But again, if we reduce the inductance in

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the jar circuit to 50,600 centimeters and the capacity to 0·0007 microfarad, we set up oscillations with a frequency of 834×10^6, or nearly three times that of the fundamental. Under these conditions we find that the glow discharge from the spiral distributes itself so as to produce a dark place about sixty centimeters from the open end of the helix; and by exploring the distribution of electric force round the helix by means of a Neon vacuum tube, as explained in the October number of TECHNICS, we can ascertain that there is a node of potential at this point, and a distribution of electric tension along the wire, as represented by the ordinates of the dotted lines in the second diagram from the top in Fig. 7. Hence, the distance from the node to the end of the spiral E in contact with the jars, must be one-half of a wave-length, and it is equal to 140 centimeters. The wave-length of the first harmonic is, therefore, 280 centimeters. Multiplying this wave-length by the corresponding frequency (834×10^6) of the jar circuit, we have the velocity of the wave; this is 233×10^6 centimeters per second, in fairly close agreement with the value obtained from the fundamental vibration.

We can proceed to reduce still more the capacity and inductance of the jar circuit, and create frequencies which stand to that of the fundamental in the ratio of 5, 7, 9, and 11 to 1. Corresponding to this, we shall find that stationary electric waves are set up on the helix which have 3, 4, 5 and 6 nodes, including the node at the junction

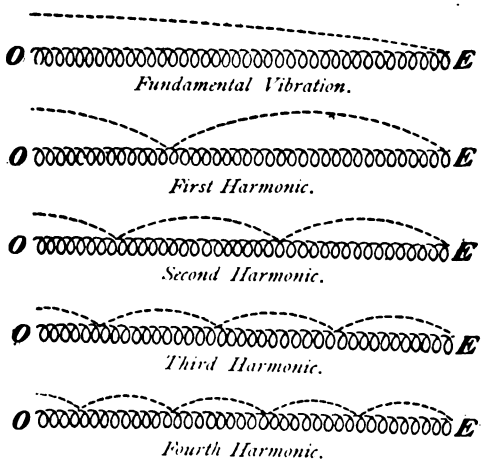

FIG. 6.—TO ILLUSTRATE THE PRODUCTION OF THE FUNDAMENTAL VIBRATION AND ITS VARIOUS HARMONICS IN A WIRE SPIRAL.

O, *free end of spiral.*
E, *end of spiral connected to Leyden jars.*

with the exciting circuit. Measuring the distance from node to node, we can obtain the wave-lengths of these several harmonics, and we can calculate from them and the corresponding frequencies the wave velocity. The identity of the calculated velocity in all cases shows that the number so obtained represents the constant velocity of the potential wave along the spiral.

It also shows us that such a helix can have set up in it a distribution of electric potential and high-frequency current, which is perfectly analogous to the distribution of air pressure and velocity in the case of a closed organ pipe sounding its various overtones.

One thing especially the student of the subject should notice. In the case of an ordinary steady or low-frequency electric current, the current has always the same strength and direction in all parts of the circuit at the same moment, though it may vary from instant to instant. In the case of high-frequency currents this, however, is not the case; currents may be flowing in opposite directions, and with very different strengths at the same moment, in different parts of the same wire.

These principles of resonance are of the greatest utility in connection with the modern practice of Hertzian wave or so-called wireless telegraphy. We have already explained the principles of the transmitter or radiator, by means of which long or short trains of electric waves can be sent out; and also the manner in which these set up feeble electromotive forces and oscillations in a distant aerial wire. If a wire or rod is set up vertically, having one end connected to an earth plate and the other end insulated, such a rod, if insulated, may be considered to be the inner coating of a Leyden jar of which the earth is the outer coating. Hence it has a certain capacity. Moreover it has an inductance as well, and, therefore, a certain time-period. Approximately speaking, if h is the height of the rod in centimeters, its natural time-period is not far from $3 \times 10^{10}/4h$; or if H is the height in feet, then the time-period is $10^9/4H$.

Hence for vertical wires of 180 to 200 feet or so, the natural time-period of electrical oscillation is about a millionth of a second. This can be varied within somewhat wide limits by the introduction of a variable inductance into the circuit of the rod near its base. Let us suppose that we have electric waves travelling through space, the wave-length of which is anything between 200 feet and 1000 feet; we can adjust the inductance of

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the rod to such a value that it is *syntonised* or *tuned* to their period, and has stationary electric oscillations set up, which are either the fundamental or a higher harmonic. If we then insert, in series with the rod or aerial, the primary circuit of a small air core transformer, we have an arrangement by which feeble trains of waves create corresponding variations of electric potential between the ends of the secondary terminals of the air-core transformer (see Fig. 7). We may detect these electric

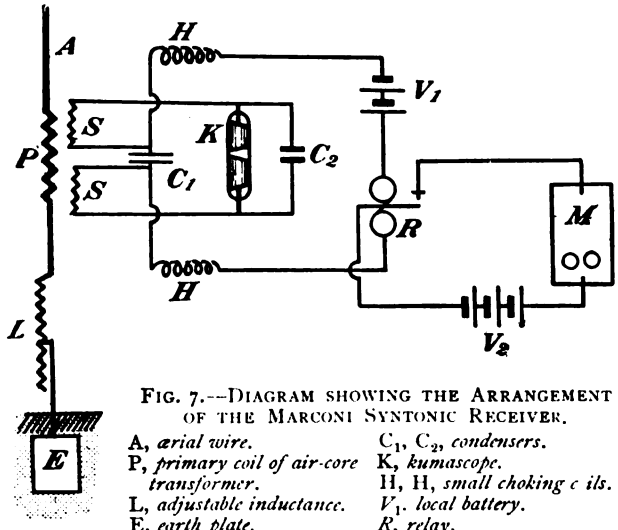

FIG. 7.—DIAGRAM SHOWING THE ARRANGEMENT OF THE MARCONI SYNTONIC RECEIVER.

A, *aerial wire.*
P, *primary coil of air-core transformer.*
L, *adjustable inductance.*
E, *earth plate.*
S, secondary of air-core transformer.
C_1, C_2, *condensers.*
K, *kumascope.*
H, H, *small choking coils.*
V_1. *local battery.*
R, relay.
M, Morse printer.
V_2, *large battery.*

oscillations in the aerial by connecting to the terminals of this transformer, or inserting in the circuit of the aerial, some device of the kind called a kumascope. Thus in one form of the Marconi receiver, the nickel-silver filings kumascope already described is used, and the arrangements of the receiver are as shown in Fig. 7. In this, diagram A represents the aerial wire, and P the primary coil of the air-core transformer in series with it. L is the adjusting inductance, and E the earth plate. The secondary circuit S of the air core transformer is cut in the middle, and a condenser C_1 inserted. K is the kumascope, and C_2 a smaller condenser. From the terminals of C_1 wires are led through small choking coils H, H to the local battery V_1 and relay R. The relay closes the circuit of a larger battery V_2 and works a Morse printer M. The following syntonisations have to be effected. The circuit of the kumascope, consisting of the secondary of the transformer and the condensers C_1 and C_2, has to be in syntony with the circuit of the aerial, determined by the inductances of A, P and L, and the capacity of the aerial: their period has to agree with that of the selected waves. Under these conditions the kumascope is not readily affected or affected at all, except by prolonged wave-trains of the selected period.

Marconi has so perfected these devices that the wave-trains sent out from his power stations at Poldhu in Cornwall, and Cape Breton in Nova Scotia, do not affect the receivers placed on board ships crossing the Atlantic or elsewhere, except those tuned to them. Hence certain Atlantic liners which are provided with the proper receivers can receive news telegraphed to them from the power stations during their voyage across the Atlantic; news is now regularly published in small newspapers edited and printed on board these ships each day. On the other hand, other ships are provided only with apparatus intended to enable them to communicate with each other and with certain shore stations, and these last receivers are not affected by the waves from the long-distance stations.

The principles of resonance thus enable a selective wireless telegraphy to be conducted, which, though to some degree limited in its possibilities, is yet of the greatest practical use.

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THE METALLOGRAPHY OF STEEL.

By PERCY LONGMUIR, of the National Physical Laboratory.

THE structural constituents of steel have been previously indicated in this magazine;* it may, however, be well to briefly recapitulate the three essential ones. Thus, pure iron is micrographically known as "ferrite": it forms polyhedral crystals which sectionally show the typical crystal junctions of Figs. 1 and 2. "Cementite" denotes the hard carbides of iron, whilst "pearlite" is the term applied to a mixture of ferrite and cementite. This mixture may be coarse, or close and compact. The former condition is met with in annealed steels, the pearlite then consisting of alternate striæ of ferrite and cementite, and presenting a laminated appearance, as shown in Fig. 9. Intimate or compact pearlite is formed under conditions which preclude the segregation of the two constituents (see Fig. 10).

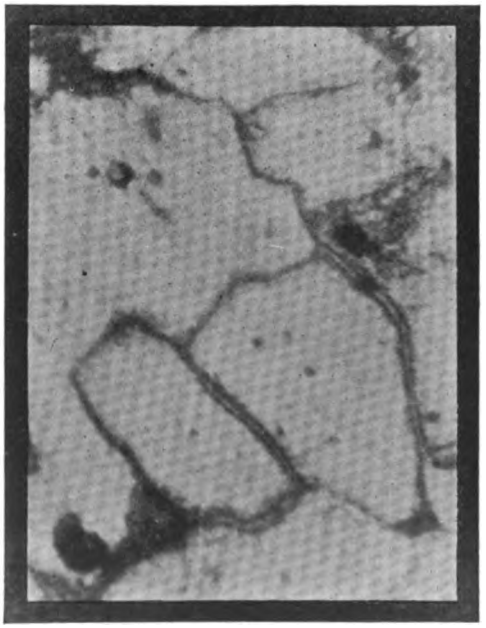

FIG. 1.—NEARLY PURE IRON AS CAST.
Magnified 360 diameters.

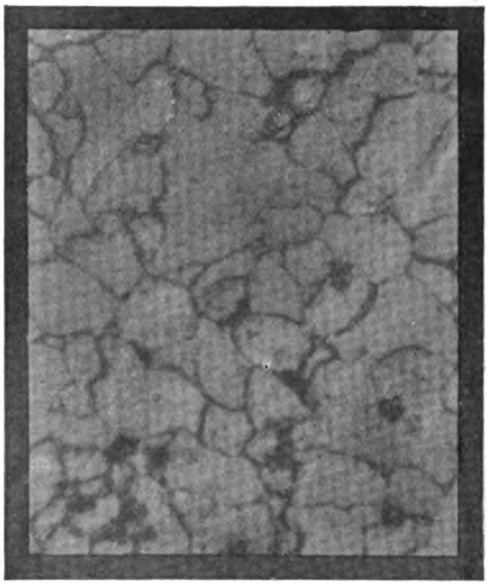

FIG. 2.—IRON REPRESENTED IN FIG. 1, AFTER FORGING.
Magnified 360 diameters.

The influence of carbon on iron has also been described, and it will be remembered that each increment of carbon added to iron results in a corresponding increase of pearlite. As the areas of pearlite increase, the free ferrite diminishes, finally disappearing at a content of 0·89 per cent. of carbon. This content is described by its discoverer, Professor Arnold, as the "saturation point"; that is to say, a steel containing 0·89 per cent. of carbon in the annealed condition is micrographically formed of one constituent, pearlite. Further addition of carbon beyond the saturation point results in the rejection of the surplus cementite to cell walls embracing areas of pearlite.

This cursory summary conveys some idea of the utility of the microscope in studying the constitution of steels. A no less important service is rendered by the light thrown on condition, or the influence of work and treatment. It is now proposed to examine, microscopically, the structural influence of various conditions on which the evidence is clear; and, later, to treat of a certain constitutional phase on which the evidence is not clear.

* A. Hiorns, TECHNICS, January, 1904.
Percy Longmuir, TECHNICS, April, 1904.
H. C. H. Carpenter, M.A., Ph.D., TECHNICS, May, 1904.

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The importance of condition is well shown in the following table :—

	Carbon per cent.	Manganese per cent.	Condition.	Maximum Stress. Tons per square inch.	Elongation per cent. on 2 inches.	Reduction of area per cent.
1	0·08	0·06	Cast .	18	20	30
	0·08	0·06	Forged	22	45	60
2	0·35	0·88	Cast .	28	18	18
	0·35	0·88	Forged	41	28	54

These results emphasise the value of work on cast material, a value not indicated by chemical analysis. The foregoing iron and medium steel are, in their respective conditions of cast and forged, of precisely the same analysis, and represent exactly the same material. Yet the forged material is measurably superior to the cast, and offers a telling illustration of the influence of condition.

It will not be without profit to follow the microscopical indications of varying conditions, taking first the pure iron of the foregoing table. Fig. 1 reproduces the iron as cast, whilst Fig. 2 gives the structure of the same iron after forging. There are no chemical differences, and an examination of the two figures will show the only difference to be a crystalline one. The influence of forging may be described as tending to dovetail the crystals into one another, a type of interweaving which, as the tensile tests show, most effectually strengthens the intercrystalline cohesion. Internal cohesion may be estimated by the appearance of the crystal junctions, and the manner in which the crystals interlock. Thus the junctions of Fig. 2 indicate a more "dovetailing" type of crystallisation than those of Fig. 1 ; consequently, when the iron is subjected to a tensile stress, the greater cohesion acting between the crystals results in the forged metal carrying a greater load, and undergoing greater distortion before fracture. This distortion, measured by the elongation, and the contraction of area, is not nearly so evident with the comparatively loose crystals of the cast material.

Passing from iron to steel, a convenient example will be found in the one of which the mechanical properties have already been given. The structure of this steel as cast is reproduced in Fig. 3, and its sharp, distinct character will be readily noted. In this condition the steel has a fairly high tensile strength, but, as its structure indicates, is brittle. It is, of course, well known that all steel castings are annealed before use, a process which consists of heating the castings to a temperature between 800° C. and 900° C., maintaining them there for some time, and then slowly cooling. This process serves a twofold purpose—first, internal strains, due to inequalities in the thickness of the castings, are relieved by the slow cooling; and, second, the sharp boundaries between the areas of pearlite and ferrite are broken

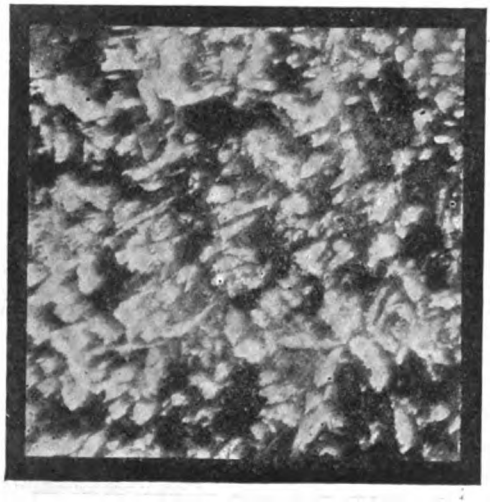

FIG. 3.—STEEL AS CAST.

Magnified 58 diameters.

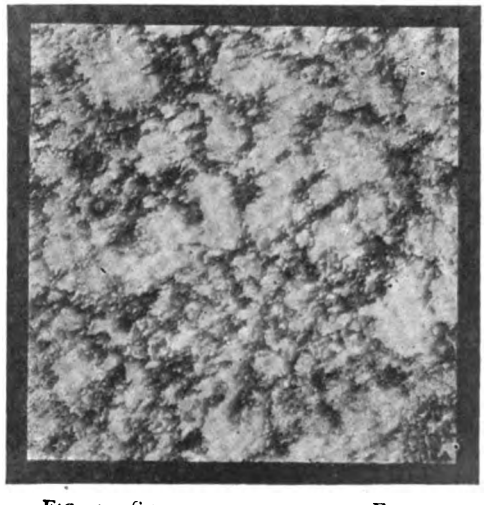

FIG. 4.—STEEL REPRESENTED IN FIG. 3, AFTER ANNEALING.

Magnified 58 diameters.

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down. Fig. 4 shows the structural changes induced by annealing: the characteristic merging of the two constituents, and the disappearance of the sharp structure will be noted. Carrying the examination further, the structural influence of forging is shown in Fig. 5. Here, if a contradiction in terms is permissible, the characteristic features lie in the compact and "broken-up" type of structure. The former is evident, whilst the distribution of ferrite and pearlite in relatively small areas gives the broken-up appearance. In studying Figs. 3, 4 and 5, it must be remembered that they represent one steel; though the structures are so widely different, the chemical analyses of the three are identical.

These examples sufficiently illustrate the structural changes developed by annealing or forging cast metal. Next in order comes

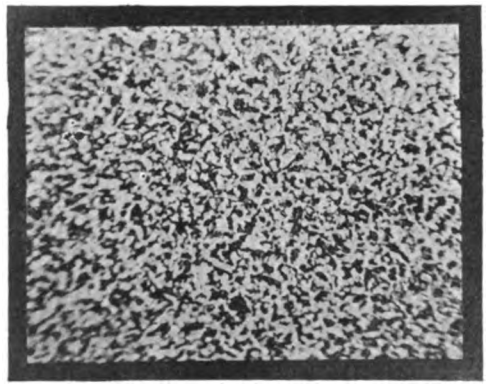

FIG. 5.—STEEL REPRESENTED IN FIG. 3, AFTER FORGING.
Magnified 58 *diameters.*

the influence of heat treatment, or, more correctly, the influence of the rate of cooling. It is generally recognised that with all crystalline bodies, the slower the rate of cooling the more perfect the type of crystallisation – a well-marked feature with all metals and alloys. As the metal iron crystallises at a much lower temperature than its solidification point, the influence of varying rates of cooling may be readily examined. In the following case three pieces of Swedish iron were heated to 1000° C., and three different rates of cooling obtained, thus—

(*a*) From 1000°C. to atmospheric temperature, 5 hours.
(*b*) From 1000°C. to atmospheric temperature, ½-hour.
(*c*) From 1000°C. to atmospheric temperature, almost instantaneous.

(*a*) was obtained by cooling the piece down in the muffle; (*b*) by cooling in air; and (*c*) by quenching. The corresponding struc-

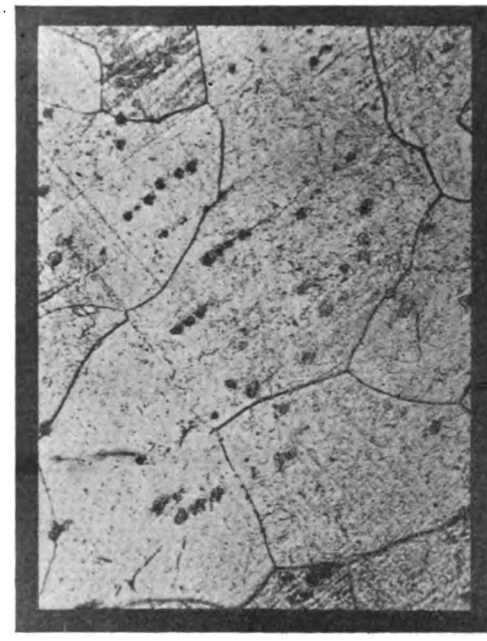

FIG. 6.—NEARLY PURE IRON SLOWLY COOLED.
Magnified 150 *diameters.*

tural changes are shown in Figs. 6 to 8. Thus Fig. 6 shows a large and regular type of crystallisation; Fig. 7 a smaller, but still fairly regular one; whilst Fig. 8 shows con-

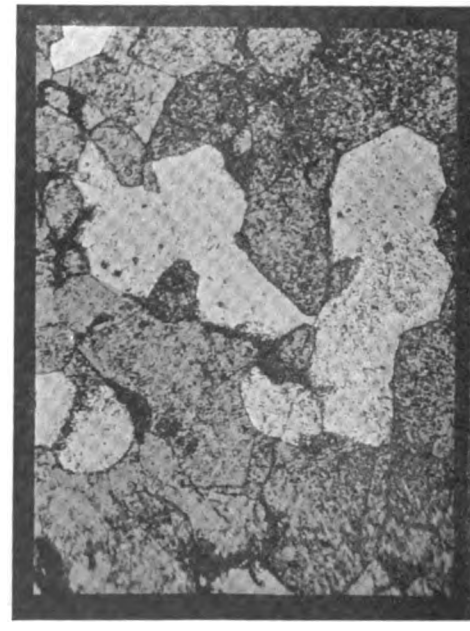

FIG. 7.—IRON REPRESENTED IN FIG. 6, BUT MORE QUICKLY COOLED.
Magnified 150 *diameters.*

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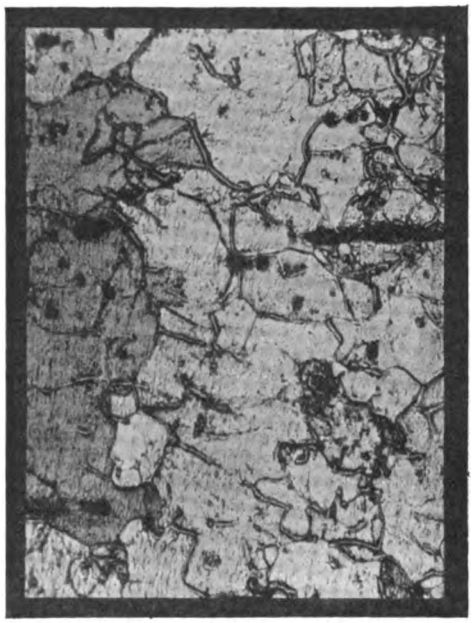

FIG. 8.—IRON REPRESENTED IN FIG. 6, AFTER QUENCHING.

Magnified 150 diameters.

siderable distortion. As far as mineralogical hardness is concerned, the three structures are equal, quenching developing no greater hardness than that possessed by the slowly cooled specimen. As in the previous cases, these structures represent one metal, and the analyses throughout are uniform. Naturally, with a pure iron of this type, containing only one constituent, ferrite, well-marked structural changes cannot be expected from varying rates of cooling. The only evidence of varying treatment is shown in the more or less perfect crystallisation, and, micrographically, may be studied by comparing the crystal junctions as indicated. When, however, carburised iron is substituted for carbonless iron, well-marked structural changes are shown; and it follows that with the steels a study of varying rates of cooling is closely allied to the relationship existing between iron and carbon. For example, it has been shown that quenching, in the case of pure iron, results only in a crystalline distortion; whereas this treatment applied to a steel results in practically a new metal possessing properties entirely distinct from those of the unquenched steel, and also an entirely different type of structure. However, it will be well to reserve hardened steels for the concluding portion of this study.

The constituent pearlite has been referred to in the opening summary, and its occurrence as laminated and granular indicated. As a matter of fact, pearlite may be found in every possible state of division between coarse and exceedingly fine. With pure metals, the rate of cooling determines the perfection or otherwise of the type of crystallisation; similarly, the rate of temperature fall determines the appearance of the pearlite in a steel. With pure iron, slow cooling produces the largest and most geometrical crystals; with the pearlite of a steel, slow cooling gives the necessary time for its constituents, ferrite and cementite, to segregate, resulting in laminated pearlite. On the other hand, rapid cooling (not quenching) prevents the segregation, and, as would be naturally expected, the pearlite is in a fine state of division, the fineness increasing with the rapidity of the cooling. Unsegregated pearlite is, therefore, common to all steels rapidly cooled, whilst the segregated or laminated type is characteristic of slowly cooled steels. These two types impart to steel very different properties, and it is usually found that a steel containing well laminated pearlite possesses high ductility, whilst a similar one containing its pearlite in the unsegregated form will show less ductility, but yield a much higher limit of elasticity and breaking strength. These facts are by no means new: the gain in

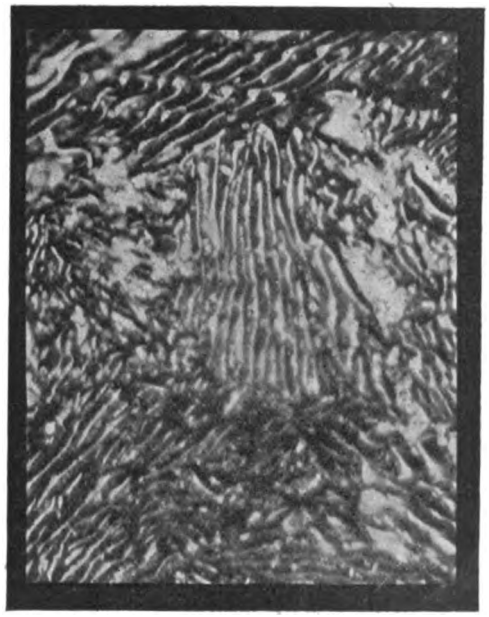

FIG. 9.—PEARLITE AREA OF WELL ANNEALED STEEL CASTING.

Magnified 1,000 diameters.

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hardness due to rapid cooling has long been known and utilised in works practice, whilst the essential difference between segregated and unsegregated pearlite was described by Professor Arnold in 1895.*

To illustrate these differences in state of division, the author has selected an example from actual steel foundry practice. It has been stated that the gain in hardness has been long known; thus in steel foundry practice, castings which have been over-annealed and thereby rendered too soft, are by heating to a full-red heat, and cooling at a rate determined by the size and form of the casting, returned to the desired degree of hardness. Fig. 9 shows the coarse pearlitic structure developed by annealing; the particular casting of which this structure is typical had, in working life, to resist considerable abrasion, and, therefore, with pearlite in this condition, would prove too soft to meet service conditions successfully. After heating to a full red heat and cooling in air, the structure shown in Fig. 10 was produced, and the casting met successfully all service requirements. The previously described unsegregated pearlite will be readily recognised in Fig. 10; and a comparison of the two structures sufficiently illustrates the influence of differing rates of cooling.

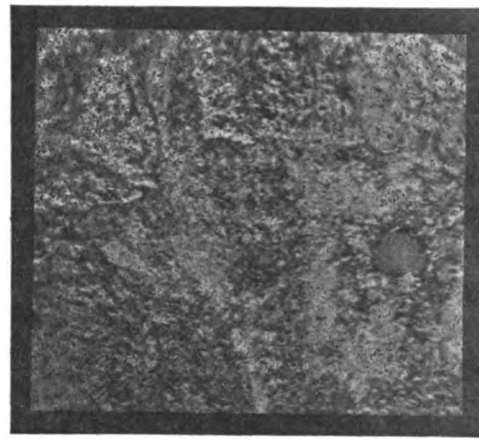

FIG. 10.—STEEL SAME AS IN FIG. 9, AFTER HEATING TO RED HEAT AND COOLING IN AIR.

Magnified 1,000 diameters.

The type of pearlite shown in Fig. 10 is often described as "sorbite," indicating a distinct constituent. In the present state of knowledge, "sorbite" can hardly be accepted as denoting a distinct and separate constituent of carbon steels. A careful examination of the evidence adduced leads to the conclusion that sorbite, instead of representing a distinct entity, represents only pearlite in an exceedingly fine state of division: in other words, it has been produced under conditions of cooling which have retarded the segregation of its constituents, ferrite and cementite. Admittedly there is urgent need for much further research on this condition of pearlite. Until our present hazy ideas are replaced by exact knowledge, the better plan, and certainly the safer one, is to regard sorbite not as a constituent, but as a type of structure induced by particular treatment. Viewed in this light, the term "sorbitic pearlite" is permissible, since it describes a type of structure, but does not necessarily indicate a distinct constituent. An exact definition cannot be applied to an inexact body; it is, however, scientifically permissible to make use of a temporary term indicating a substance of which the exact nature is not yet known. Such is the distinction between "sorbite" and "sorbitic pearlite."

The changes studied up to the present are of a fairly simple character, involving only differences in crystalline condition; on passing to harder steels the study assumes a more complex character. For instance, tool steel is met with in the three well-known states of soft or comparatively so, hardened, and tempered. The soft state is characteristic of the steel as received from the rolling mill, which may then be drilled or machined. The same steel, after heating to a red heat and quenching in water, acquires an intense hardness, and is quite beyond the ordinary operations of drilling or turning. These varying properties of one steel may be shown in a further and, possibly, more telling manner by taking three thin strips and subjecting them to the following treatment:—

(1) Heating to a red heat and slowly cooling;
(2) Heating to a red heat and quenching in water; and
(3) Heating to a red heat, quenching in water and subsequently reheating to a blue heat.

By a simple bending test it will be found that (1) will bend to a certain angle, showing no tendency to spring back, whilst (2) will not bend at all, but fracture sharply when the moment is high enough. On the other hand, (3) will not only bend slightly, but on removal of the bending force, the strip will spring

* Proceedings, Institute of Civil Engineers, Vol. CXXIII.

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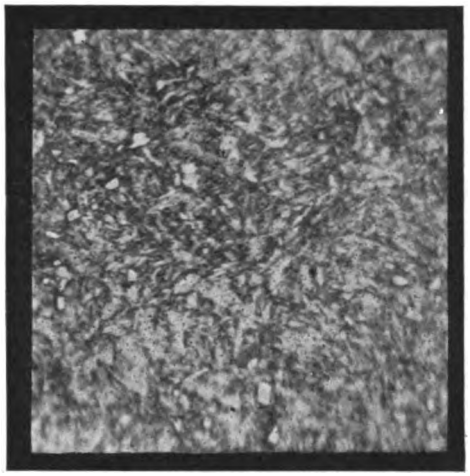

FIG. 11.—MICRO-STRUCTURE OF FILE.
Magnified 1,000 diameters.

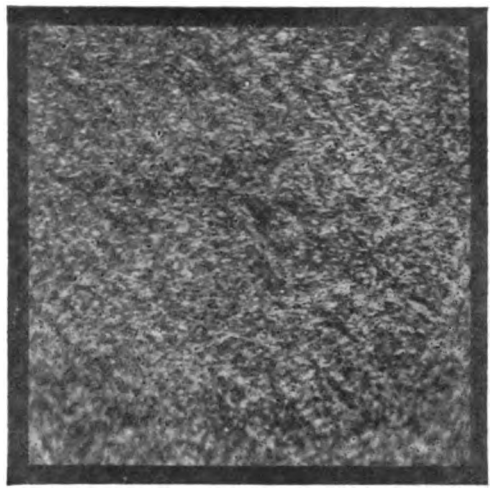

FIG. 12.—MICRO-STRUCTURE OF HACK-SAW BLADE.
Magnified 1,000 diameters.

back to its original position. Commercially, these conditions have much value, and in practice, examples of the dead-hard condition will be found in tools, razors and the like, whilst examples of the tempered state are met with in wood saws, table knives, and the like.

The structures of commercial hardened and tempered steels ought to possess some interest; however, there are a few essential features to note before taking up a detailed examination.

1. The structure of a commercial hardened steel is never sharp and distinct; in many cases it cannot be clearly resolved at a high magnification.

2. A clear or pronounced structure indicates faulty hardening conditions.

3. The structure existing at the hardening temperature is not altogether preserved in the cold metal, for on immersing the red-hot steel in water a definite interval elapses before the temperature of the water is reached. This short interval permits of some structural change.

4. A consideration of (3) will show that the larger the mass, the less the quenching effect in the centre; for, with mass, the cooling action is sensibly diminished as it travels inwards. The portion most slowly cooled will, therefore, show the greatest segregation in the cold metal, and the structure will vary from exterior to centre, according to the rate of cooling. This feature is of importance when we consider the action of quenching: it must, however, be added that the majority of hardening operations are conducted on articles of comparatively thin section.

The absence of definite character in a commercially hardened steel will be noted on examining Fig. 11. This particular structure represents that of a fourteen-inch flat file: it practically consists of a dark groundwork, interspersed by small white areas. As a further example, Fig. 12 reproduces the structure of a hack-saw blade, in other words, that of a slightly-tempered steel. In order to avoid any tempering action, both these sections were polished entirely by the wet method, during which no appreciable rise in temperature occurred. The two structures present only slight differences; they are figured here merely to show typical and faithfully obtained types of commercial hardened steel: a discussion of these structures will follow later.

(*To be continued.*)

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THE ELECTRO-MAGNETIC THEORY.

Explained without the Use of the Higher Mathematics.

PART III.—QUANTITATIVE RELATIONS.

By EDWIN EDSER, A.R.C.Sc.

IN the October number of TECHNICS, the qualitative properties of stationary tubes of force were deduced from experimental data; it was there shown that the force exerted by one electric charge on another can be explained in terms of the electric tubes of force associated with the two charges, while the force exerted by one magnetic pole on another can be explained in terms of the magnetic tubes of force associated with the two poles. The fundamental properties of electric and magnetic tubes of force are precisely similar: in either case the tubes tend to contract longitudinally and to expand laterally, and these two tendencies determine their distribution in the space surrounding the charges or poles. Statical experiments afford no indication as to whether the electric or the magnetic tubes should be considered to be the real entities; but in the November number of TECHNICS it was shown that the magnetic field due to an electric current can be explained in terms of moving electric tubes of force, so that it appears probable that all magnetic phenomena may admit of a similar explanation, with the result that only the electric tubes need be considered to be real entities. Nevertheless, the properties of magnetic tubes of force can still be used in our reasoning with confidence, since these properties have been deduced from experimental data; it is only necessary to remember that magnetic phenomena are really due to the motion of electric tubes of force, which alone resemble material bodies in possessing inertia.

The next step in our investigation must be to obtain quantitative information as to the properties of tubes of force. So far as statical properties are concerned, a result obtained for the electric tubes will apply, with but small modification, to the magnetic tubes. In the ensuing quantitative investigations some formulæ of the greatest importance in electrical engineering will be deduced in a very simple manner.

In the first place, let us consider the distribution of tubes of force around a charged spherical conductor placed in the middle of a room. As already proved, the tubes distribute themselves symmetrically around the charged sphere, each tube leaving the surface normally; if, in imagination, we prolong all the tubes within the sphere (Fig. 1) they will meet at its centre. Thus the field at any point outside the sphere will be the same as if all the tubes started from the centre of the sphere; and since the charge consists merely of the ends of tubes of force, it follows that the field outside the sphere is identical with that which would be produced if the sphere were removed and its charge concentrated at the point previously occupied by its centre. Thus, at a distance r from the centre of the sphere, the field strength will be equal to $Q/(\kappa r^2)$, where Q is the charge, in electro-magnetic units, imparted to the sphere, and κ is the dielectric constant of the æther.

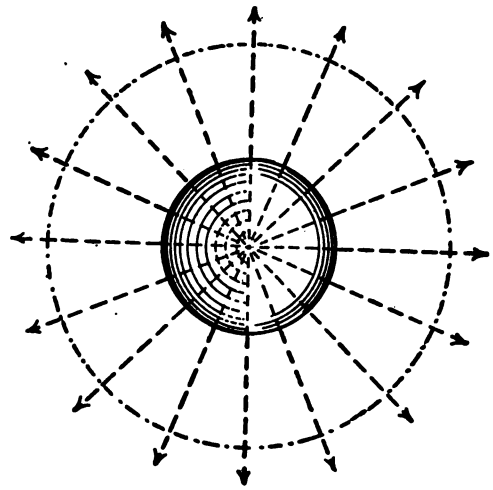

FIG. 1.

Let us now suppose that the charge Q corresponds to the ends of n tubes of force; then n tubes of force will proceed radially from the sphere, as if they started from its centre. If an imaginary spherical surface of radius r be drawn concentric with the charged sphere, n tubes of force will pass through this surface, equal numbers of tubes passing through equal

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areas on different parts of it. Since the area of a sphere of radius r is equal to $4\pi r^2$, it follows that the number of tubes passing normally through unit area of the surface is equal to $n/(4\pi r^2)$.

The field strength (force per unit charge) at a point varies inversely as the square of the distance of this point from the centre of the charged sphere; also the number of tubes of force passing normally through unit area varies inversely as the square of the distance of the area from the centre of the charged sphere. Thus, since n by definition is proportional to Q, we may choose n so that the number of tubes of force passing normally through unit area at a given point is equal to the field strength at that point. For this to be true, we must have

$$\frac{n}{4\pi r^2} = \frac{Q}{\kappa r^2}; \quad \therefore \quad n = 4\pi Q/\kappa.$$

From this we infer that *the electro-magnetic unit of charge consists of the ends of* $4\pi/\kappa$ *tubes of force.* It is, of course, unnecessary to assume that each tube of force, as defined above, is indivisible; we may consider each tube to consist of a bundle of elementary tubes, each of which may possibly be an indivisible entity. The tube of force with which we have to deal has the property that at a point where its cross-sectional area is equal to one square centimeter, the field strength is equal to one dyne per unit charge, if the tube extends through a vacuum or (to a near approximation) through air.

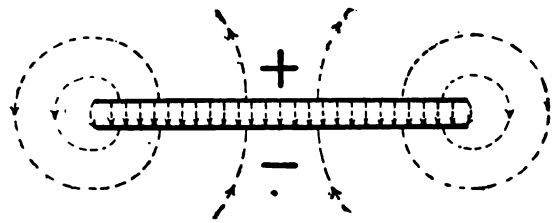

FIG. 2.

In general, the force per unit charge at a given distance r from a charge Q depends, not only on the values of Q and r, but also on the nature of the surrounding medium: if the charge Q and the unit test charge are immersed in paraffin oil or any non-conducting liquid, the force between them will be smaller than if the charges were placed in the same relative positions in empty space. Thus, in general, the field strength at a distance r from a charge Q is equal to $Q/(K\kappa r^2)$, where K is a constant the value of which depends on the nature of the surrounding medium; it is termed the *specific inductive capacity* of the medium.

The number of tubes of force leaving a given charge is the same whatever may be the nature of the surrounding medium; in other words, the medium influences the properties, but not the number, of the tubes of force. Thus N tubes of force per square centimeter will correspond to a field strength of N dynes per unit charge in air, or to N/K dynes per unit charge in a medium of specific inductive capacity K.

In a manner similar to that used above, it can be proved that $4\pi m$ magnetic tubes of force leave a magnetic pole of strength m; the field strength at a distance r from the pole is equal to $m/(\mu r^2)$, where μ is the permeability of the surrounding medium (for the æther, $\mu = 1$). A magnetic field of N tubes per square centimeter corresponds to a force of N dynes per unit pole in empty space, or to N/μ dynes per unit pole in a medium of permeability μ.

We can now proceed to investigate the phenomena attending the charge and discharge of a plane condenser. Such a condenser consists of two plane metallic plates placed parallel to each other at a small distance apart. The operation of charging the condenser consists in squeezing tubes of force, each extending from one plate to the other (Fig. 2), into the space between the plates. At a reasonable distance from the edges of the plates the tubes will be straight, uniform in shape, and equal in sectional area; the number of tubes leaving unit area of one plate will pass through unit area at any point in their course to the other plate. If the areas of the plates are large in comparison with the distance separating them, then nearly all the tubes will extend straight across from one plate to the other; the few that take the more roundabout course from the upper surface of the upper plate to the lower surface of the lower plate (Fig. 2) may in this case be neglected. Then if A represents the area of the upper plate, and (+Q) represents the charge given to the upper plate, $4\pi Q/\kappa$ tubes of force will leave this plate, and $4\pi Q/(\kappa A)$ will leave unit area of it, and pass through unit area at each point in their course to the lower plate. If the space between the plates is free from any material medium (or, to a near approximation, if there is no medium save air between the plates), the number N of tubes of force passing normally

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through a square centimeter is equal to the field strength in dynes per unit charge: thus the field strength at any point between the plates (save near the edges of the latter) is equal to $4\pi Q/(\kappa A)$ dynes per unit charge.

The *difference of potential* between the plates is defined as the work done in moving a unit (+) charge from one to the other (say, from the lower to the upper). Let d be the perpendicular distance from one plate to the other; then if a unit (+) charge is moved through the distance d from the lower to the upper plate, the uniform force $4\pi Q/(\kappa A)$ must be overcome, and hence the work performed, or the potential difference V between the plates, is given by—

$$V = \frac{4\pi Q}{\kappa A} \times d \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If the space between the plates is filled with a medium of specific inductive capacity K, the charge remaining unaltered, then the number, N, of tubes of force per square centimeter will have the same value as before, but the force per unit charge will be equal to $N/K = 4\pi Q/(K\kappa A)$, and the difference of potential will have the value

$$V = \frac{4\pi Q d}{K\kappa A} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Hence we see that if a condenser receives a charge Q, and the resulting potential is measured, first when the plates are separated by air, and secondly, when they are separated by a medium of specific inductive capacity K, then the ratio of the first to the second potential gives the value of K. This result may be stated somewhat differently. We may define the *capacity of a condenser* as the charge that will produce unit difference of potential between the plates. Let C represent the capacity of the air condenser, while C_1 represents the capacity when the space between the plates is filled by the substance of specific inductive capacity K. Then substituting V = 1, and Q = C in (1), we obtain—

$$C = \frac{\kappa A}{4\pi d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Substituting V = 1, and Q = C_1 in (2), we obtain

$$C_1 = \frac{K\kappa A}{4\pi d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4),$$

so that C_1 is K times as large as C. Thus the specific inductive capacity of a medium is equal to the ratio of the capacity of a condenser when the space between the plates is filled with the medium, to the capacity of the same condenser when the space between its plates is occupied by air (more strictly speaking, merely by the æther).

In squeezing tubes of force into the space between the plates of the condenser, work must be done, just as when air is compressed by the aid of a pump. It follows from this that the charged condenser possesses a store of energy equal to the work done in charging it. Now we may imagine the condenser to be charged in the following way: The lower plate may be imagined to contain equal numbers of positively and negatively charged particles, each positive charge being united to a negative charge by tubes of force shrunk up to molecular dimensions. We may next imagine that the positive charges are picked out one by one and conveyed from the lower to the upper plate, leaving the negative charge behind; in this process the tubes of force joining each pair of particles are stretched out so as to pass from one plate to the other, and work is done. If the condenser is initially uncharged, the work done in moving the first (+) element of charge from the lower to the upper plate will be vanishingly small. Let the final potential of the charged condenser be equal to V; then, since the potential is equal to the work done in moving a unit (+) charge from the lower to the upper plate, the work done in carrying the last element of charge $(+q)$ over this path must be equal to Vq. Thus the work done in transferring a charge $(+q)$ varies from zero at the commencement of the charge, to Vq at the end of the charge, and increases uniformly between these limits: hence the *average* work done on an element $(+q)$ is equal to $(V/2)q$, or the average work *per unit charge* is equal to V/2. Let Q be the total charge which produces the potential V: then the total work done in imparting this charge to the condenser is equal to the average work per unit charge multiplied by the total charge, or $(V/2) \times Q = (VQ)/2$. This result also gives us the total energy of the charged condenser.

If the medium between the plates has a specific inductive capacity equal to K, the potential V produced by the charge Q is given in (2). Thus the energy of the charged condenser is equal to—

$$V\frac{Q}{2} = \frac{4\pi Q d}{K\kappa A} \times \frac{Q}{2} = \frac{2\pi Q^2 d}{K\kappa A} \quad . \quad . \quad . \quad (5)$$

This equation affords us some valuable information. In the first case it shows conclusively that *electricity is not energy*: this is quite clear from the fact that the energy of

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the condenser does not merely depend on Q, but is proportional to d, the distance between the plates or the length of the tubes of force. In other words, the energy of an electric charge depends not only on the charge, but on the length and distribution of the tubes of force associated with it. It is thus natural to locate the energy in the space between the plates, that is, to look on the tubes of force as the seat of the energy.

Since the tubes of force tend to contract, the plates will be pulled toward each other with a certain definite force. The tubes leaving either plate will exert a certain tensile-stress of T dynes per square centimeter; we must now determine the value of T. The total force on either plate, of area A square centimeters, is equal to T A dynes. Let us now suppose that we pull the plates a little farther apart, so that the distance from one to the other is increased from d centimeters to $(d+\delta)$ centimeters, where δ is small. In this operation we must perform an amount of work equal to $T A \delta$ ergs, and an equivalent amount of energy must have been imparted to the charged condenser. But the final energy of the charged condenser will be found by substituting $(d+\delta)$ for d in (5), since the distance between the plates is now equal to $(d+\delta)$. Thus we have

Original energy + *Work performed* = *Final energy*,

$$\text{or } \frac{2\pi Q^2 d}{K\kappa A} + T A \delta = \frac{2\pi Q^2 (d+\delta)}{K\kappa A}$$

$$\therefore T A \delta = \frac{2\pi Q^2 \delta}{K\kappa A}$$

$$T = \frac{2\pi Q^2}{K\kappa A^2} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The result just obtained may be thrown into a more useful form by expressing the value of T in terms of N, the number of tubes of force leaving or entering a square centimeter of either plate. We have already found that $N = 4\pi Q/(\kappa A)$; thus we may transform (6) as follows:—

$$T = \frac{4\pi Q^2}{2 K \kappa A^2} = \frac{4\pi\kappa \times 4\pi Q^2}{2 K \times 4\pi\kappa^2 A^2}$$

$$= \frac{\kappa}{8\pi K}\left(\frac{4\pi Q}{\kappa A}\right)^2 \text{ or } T = \frac{\kappa N^2}{8\pi K} \quad . \quad (7)$$

The value of T gives us the tensile stress, in dynes per square centimeter, in the direction of the tubes of force; in fact, T is the longitudinal tension per square centimeter of the tubes. Since, by definition, N tubes of force pass normally through a square centimeter, it follows that T is the resultant pull due to N tubes. Thus we have

$$\text{Pull T due to N similar tubes} = \frac{\kappa N^2}{8\pi K};$$

$$\therefore \text{Pull F due to one tube} = \frac{\kappa N}{8\pi K} \quad . \quad . \quad (8)$$

Now the value of F, the tension or pull due to a single tube of force, does not in any way depend on the length of the tube; this is proved by the fact that the length of the tube does not occur on the right-hand side of (8). In other words, if we stretch or extend a tube of force, its tension remains unchanged so long as its area is not altered; in this respect a tube of force differs from an elastic filament, in which the tension increases with the extension.

In the second place, since K for any material medium is greater then unity, it follows that the influence of the medium on the tubes of force extending through it takes the form of diminishing their tension. *The tension of each tube is inversely proportional to the specific inductive capacity* K *of the surrounding medium.*

It further appears from (8) that *the tension of a tube of force is inversely proportional to its cross-sectional area;* for if we double N, the number of tubes per square centimeter, we halve the area and double the tension of each tube. Let F_1 be the tension of a single tube of which the cross-sectional area is equal to one square centimeter; then we can obtain the value of F_1 by substituting $N = 1$ in (8) when we obtain

$$F_1 = \frac{\kappa}{8\pi K}.$$

When the number of tubes per square centimeter is equal to N, and a is the cross-sectional area of each tube, then $N a = 1$ square centimeter, and $N = 1/a$. The tension F of a tube of cross-sectional area a may therefore be written

$$F = \frac{\kappa}{8\pi K} \cdot N = \frac{F_1}{a} \quad . \quad . \quad . \quad (9).$$

We must next determine the lateral pressure per square centimeter, or the pressure which tends to make a tube of force expand laterally. Equation (9) gives us the force acting on either end of a tube of force of cross-sectional area a; since this force is independent of the length of the tube, it follows that if a tube of area a, initially one centimeter in length, has one end fixed, while the other end is allowed to move as the tube contracts to zero length, then the force (F_1/a) acts through one centimeter, and

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(F_1/a) ergs of work are performed. Thus *the potential energy per unit length of a tube of force is equal to* (F_1/a) *ergs.*

If the tube is cylindrical, the radius of its circular section being r centimeters, then $a = \pi r^2$. If the tube is one centimeter in length, the area of its curved surface is equal to $2\pi r \times 1 = 2\pi r$. Let us now suppose that this tube, while its length remains constant, expands laterally so that the radius of its circular section increases from r to $(r + \delta)$ centimeters, where δ is very small in comparison with r. Let P be the pressure in dynes per square centimeter acting on its curved surface; then since during the expansion P acts through δ centimeters, the work done per unit area of the curved surface of the tube is equal to $P\,\delta$ ergs, and the total work is equal to $2\pi r P\,\delta$ ergs. This work is performed at the expense of the potential energy of the tube, which decreases as the cross-sectional area of the tube increases. The final cross-sectional area of the tube is equal to $\pi (r + \delta)^2 = \pi r^2 \left(1 + \frac{\delta}{r}\right)^2$, so that we have

$$\left\{\begin{matrix}\textit{Initial Potential Energy}\\ \textit{of tube}\end{matrix}\right\} - \left\{\begin{matrix}\textit{Work done by}\\ \textit{tube during}\\ \textit{expansion}\end{matrix}\right\} = \left\{\begin{matrix}\textit{Final Potential Energy}\\ \textit{of tube}\end{matrix}\right\}$$

$$\text{or } \frac{F_1}{\pi r^2} - 2\pi r P\,\delta = \frac{F_1}{\pi r^2 \left(1+\frac{\delta}{r}\right)^2} \quad \ldots (10)$$

$$\text{Now } \left(1 + \frac{\delta}{r}\right)^2 = 1 + \frac{2\delta}{r} + \left(\frac{\delta}{r}\right)^2,$$

and if δ is very small in comparison with r, the value of $(\delta/r)^2$ will be negligibly small in comparison with (δ/r). In these circumstances we may write

$$\left(1 + \frac{\delta}{r}\right)^2 = 1 + \frac{2\delta}{r}$$

Hence from (10) we have

$$\frac{F_1\left(1 + \frac{2\delta}{r}\right)}{\pi r^2} - 2\pi r P\,\delta\left(1 + \frac{2\delta}{r}\right) = \frac{F_1}{\pi r^2},$$

$$\text{or } \frac{F_1}{\pi r^2} + \frac{2F_1\delta}{\pi r^3} - 2\pi r P\,\delta - 2\pi P\,\delta^2 = \frac{F_1}{\pi r^2}$$

$$\therefore 2\pi r P\,\delta + 2\pi P\,\delta^2 = \frac{2F_1\delta}{\pi r^3} \quad \ldots (11)$$

When δ is very small, the term $2\pi P\,\delta^2$ will be negligible in comparison with the first term on the left-hand side of (11), so that we have

$$2\pi r P\,\delta = \frac{2F_1\delta}{\pi r^3},$$

from which, on dividing both sides by $2\pi r\delta$, we obtain

$$P = \frac{F_1}{\pi^2 r^4} = \frac{F_1}{(\pi r^2)^2}$$

$$= \frac{F_1}{a^2} = F_1 N^2$$

$$\therefore P = \frac{\kappa N^2}{8\pi K} \quad \ldots\ldots (12)$$

On comparing equations (12) and (7), we see that the lateral pressure P, in dynes per square centimeter, is equal to the longitudinal tension T, in dynes per square centimeter. Equation (12) shows that the lateral pressure of a tube is independent of its length, but varies inversely as the square of its sectional area. The action of the surrounding medium is to diminish the longitudinal tension and the lateral pressure in the same ratio.

It is instructive to deduce these results by another method. Consider the tube of force represented in Fig. 3; this tube is similar in form to the tubes associated with a charged sphere placed in the middle of a room, the divergence of the tubes necessitating an increase in their diameters as they proceed

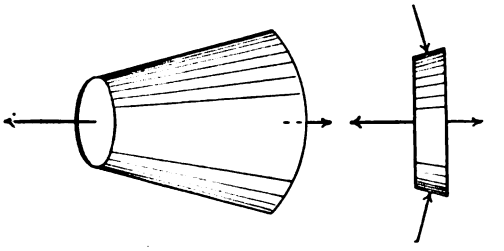

FIG. 3.

FIG. 4.

farther and farther away from the charge. Now the pull on the end of a tube of force is inversely proportional to the cross-sectional area, so that the pull on the small end of the tube is greater than that on the large end; consequently the tube cannot be in equilibrium under these pulls alone. Equilibrium is maintained by the lateral pressure on the curved surface of the tube. Let Fig. 4 represent a very thin slice of the tube cut perpendicular to its axis; let r be the radius of the smaller, and $(r + \delta)$ that of the larger plane face of this slice. Let P be the pressure exerted on unit area of the curved surface by neighbouring tubes; then for equilibrium to be possible, the pressure tending to expand the tube laterally must also be equal to P. Let a be the area of the curved surface, while θ is the inclination of a generating line to the axis; then P is inclined at an angle $\left(\frac{\pi}{2} - \theta\right)$ to the axis.

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The total force on the curved surface, resolved parallel to the axis, is equal to $P\,a \sin\theta$; $a \sin\theta$ is the projection of the curved surface on the larger plane face, and is therefore obviously equal to the difference between the areas of the opposite faces of the slice. The area of the smaller end is equal to πr^2; that of the large end

$$= \pi(r+\delta)^2 = \pi r^2 + 2\pi r\delta + \pi.\delta^2.$$

Neglecting $\pi\delta^2$ as being small in comparison with the remaining terms, we find that the difference between the areas of the plane faces of the slice is equal to $2\pi r\delta$; and since this difference is equal to $a \sin\theta$, we find that the total force of the curved surface resolved parallel to the axis is equal to $(P \times 2\pi r\delta)$. For equilibrium to be possible, the sum of the forces acting parallel to the axis must be equal to zero. Hence, since the force acting from right to left on the smaller plane face is equal to $F_1/\pi r^2$), and that acting from left to right on the larger plane face is equal to $\{F_1/\pi(r+\delta)^2\}$, we have

$$\frac{F_1}{\pi r^2} = 2\pi r P\delta + \frac{F_1}{\pi(r+\delta)^2}$$

which is equivalent to equation (10), and therefore will lead to the result already obtained.

We have found that the potential energy per unit length of a tube of area a is equal to

$$\frac{F_1}{a} = \frac{\kappa N}{8\pi K} \text{ ergs.}$$

Now N such tubes, each of unit length and sectional area $a = 1/N$, will together occupy a volume of one cubic centimeter. Hence the energy per cubic centimeter in an electric field of N tubes of force per square centimeter is equal to

$$\frac{\kappa N}{8\pi K} \times N = \frac{\kappa N^2}{8\pi K}.$$

This result could also have been obtained by dividing the total energy of the charged condenser, given in (5), by the volume of the space between the plates (*i.e.*, A d), and then expressing the result in terms of N instead of Q.

In a manner similar to that already employed, it is easy to determine the quantitative properties of magnetic tubes of force. Fig. 5 represents the lines of force in the space between two plane and parallel magnet poles; the similarity of the distribution of the lines with that of the lines in a charged condenser is at once apparent. If the pole strength is m, the number of magnetic tubes of force leaving the upper pole will be equal to $4\pi m$; and N, the number of tubes passing through a square centimeter placed parallel to the pole surfaces, will be equal to $(4\pi m/A)$, where A is the area of either pole surface. If d is the distance between the pole surfaces,

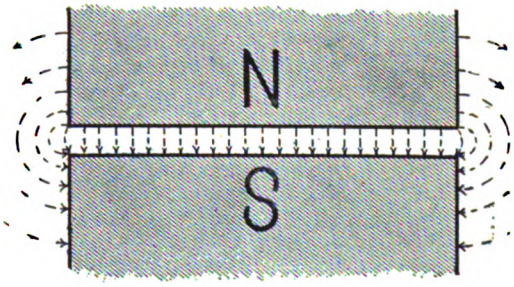

FIG. 5.

then the difference of magnetic potential (work done in moving a unit N pole from one pole to the other) will be equal to

$$\frac{4\pi m d}{A}.$$

The total energy of the tubes in the space between the poles is equal to

$$\frac{2\pi m^2 d}{A};$$

and the pull per square centimeter on either pole is equal to

$$\frac{2\pi m^2}{A^2} = \frac{1}{8\pi}\left(\frac{4\pi m}{A}\right)^2 = \frac{N^2}{8\pi}.$$

This result is familiar to electrical engineers; generally the field strength is represented by B instead of N. It is easily proved that if the space between the poles, instead of being occupied by air (for which the permeability is equal to unity), is occupied by a medium of permeability μ, then the pull per square centimeter on either pole is equal to

$$\frac{N^2}{8\pi\mu}.$$

The energy per unit volume of the magnetic field is found to be equal to $N^2/(8\pi\mu)$ for a medium of permeability μ, or $N^2/(8\pi)$ for air or any non-magnetic medium. We shall find this result of great value when investigating the quantitative properties of moving tubes of force. In the next article the most important quantitative properties of the electric current will be investigated, after which we shall be in a position to devote further attention to the motion of electric tubes of force, and determine the speed with which they travel through space.

(*To be continued.*)

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THE WATERPROOFING OF FABRICS.

By H. HIELD.

IT will be convenient to divide waterproof fabrics into two classes, *viz.*, those which are *impervious* to water, and those which are *water-repellent*. It is important to make this distinction, for, although all waterproof material is made for the purpose of resisting water, there is a vast difference between the two classes. The physical difference between them can be briefly summed up as follows: Fabrics which are completely impervious to water comprise oil-skins, mackintoshes, and all materials having a water-resisting film on one or both sides, or in the interior of the fabric. Those coming under the second heading of water-repellent materials do not possess this film, but have their fibres so treated as to offer less attraction to the water than the water molecules have for themselves.

The principal members of the first group are the rubber-proofed goods: in these the agent employed is rubber in greater or less quantity, together with other bodies of varying properties. Before enlarging on this class, it will be necessary to give a short description of the chemical and physical properties of rubber.

Rubber, or caoutchouc, is a natural gum exuding from a large number of plants, those of the *Euphorbiaceæ* being the chief source for the commercial variety. The raw material appears on the market in the shape of blocks, cakes, or bottle-shaped masses, according to the manner in which it has been collected. It possesses a dark brown—sometimes nearly black—exterior; the interior of the mass is of a lighter shade, and varies from a dingy brown to a dirty white, the colour depending on the different brands and sources. In the raw state its properties are very different from what they are after going through the various manufacturing processes, and it has only a few of the characteristics which are generally associated with india-rubber. Chemically it is a complex hydrocarbon with the formula $C_{45}H_{36}$, and appears to consist of a highly porous network of cells having several different resins in their interstices. It is perfectly soluble in no single solvent, but will yield some of its constituents to many different solvents. At a temperature of 10° C., raw caoutchouc is a solid body and possesses very little elasticity. At 36° C. it is soft and elastic to a high degree, and is capable of being stretched sixteen times its length. Further increase of temperature lessens its elastic properties, and at 120° C. it melts. While in the raw condition it has several peculiar properties, one of which is: After stretching, and cooling suddenly while stretched, it retains its new form, and only regains its former shape on being warmed. Another striking feature is its strong adhesive capacity; this property is so powerful that the rubber cannot be cut with a knife unless the blade is wet; and freshly-cut portions, if pressed together, will adhere and form a homogeneous mass. From these facts it will be seen how it differs from rubber in the shape of a cycle tyre or other manufactured form.

The most valuable property possessed by raw caoutchouc is that of entering into chemical combination with sulphur, after which its elasticity is much increased; it will then bear far greater gradations of heat and cold. This chemical treatment of caoutchouc with sulphur is known as "vulcanising," and, if properly carried out, will yield either soft vulcanised rubber or the hard variety known as vulcanite. On the other hand, caoutchouc, after vulcanising, has lost its plastic nature, and can no longer be moulded into various shapes, so that in the production of stamped or moulded objects, the customary method is to form them in unvulcanised rubber and then to vulcanise them.

Raw caoutchouc contains a number of natural impurities, such as sand, twigs, soil, etc.; these require removing before the manufacturing processes can be carried out. The first operation, after rough washing, is to shred the raw material into small strips, so as to enable the impurities to be washed out. This process is carried out by pressing the rubber against the surface of a revolving drum (A, Fig. 1), carrying a number of diagonally arranged knives, B, on its surface. A lever C presses the rubber against the knives; D is the fulcrum on which C works, E being a weight which throws back the lever on the pressure being removed. During this operation a jet of water is kept playing on to the knives to cool and enable them to cut.

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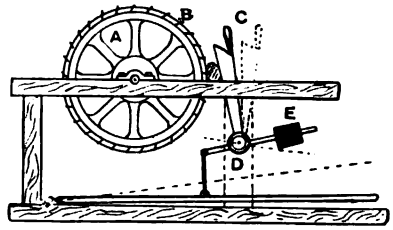

FIG. 1.

Following this comes the passage between a pair of corrugated steel rollers (as shown in Fig. 2). These rollers have each a different speed, so that the rubber gets stretched and squeezed at the same time. Immediately over the rollers a water pipe is fixed, so that a steady stream of water washes out all the sand and other extraneous matter. In Fig. 2, AA are the steel rollers, while B is a screw working springs which regulate the pressure between the rollers. The power is transmitted from below from the pulley C, and thence to the gearing.

The next operation, after well drying, is to thoroughly masticate the shredded rubber

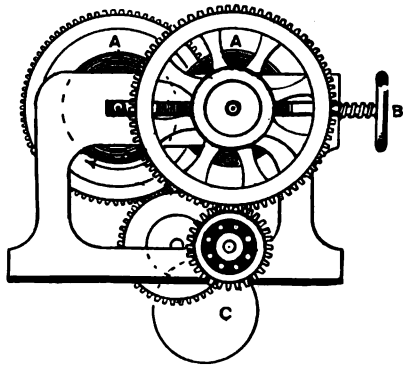

FIG. 2.

between hot steel rollers, which resemble those already described, but usually have a screw-thread cut on their surfaces. Fig. 3 shows the front view of this masticating machine, A being the rollers, while the steam pipe for heating is shown at B. Fig. 3A gives a top view of the same machine, showing the two rollers.

After passing several times through these, the rubber will be in the form of homogeneous strips, and is then ready either for moulding or dissolving. As this paper is dealing solely with waterproofed textiles, the next process which concerns us is the dissolving of the rubber in a suitable solvent. Benzol, carbon-bisulphide, oil of turpentine,

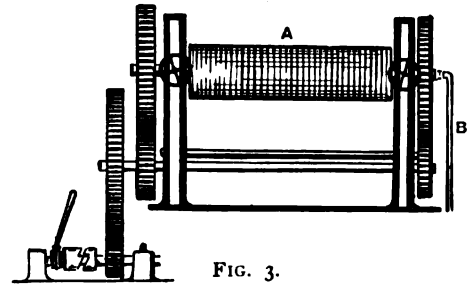

FIG. 3.

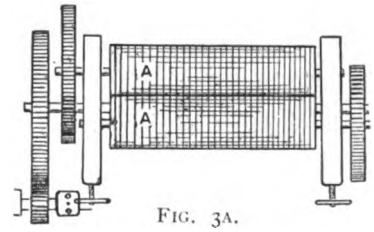

FIG. 3A.

ether, and absolute alcohol, will each dissolve a certain amount of rubber, but no one of them used alone gives a thorough solution. The agent commonly employed is carbon-bisulphide, together with 10 per cent. of absolute alcohol. Whatever solvent is used, after being steeped in it for some hours the caoutchouc swells out enormously, and then requires the addition of some other solvent to effect a complete solution. A general method is to place the finely shredded rubber in a closed vessel, to cover it with carbon-bisulphide, and allow to stand for some hours. Towards the end of the time the vessel is warmed by means of a steam coil or jacket, and ten parts absolute alcohol are added for every 100 parts of carbon-bisulphide. The whole is then kept gently stirred for a few hours. Fig. 4 shows a common type of the vessel used for dissolving rubber. In this diagram, A is the interior of the vessel, and B a revolving mixer in the same. The whole vessel is surrounded by a steam jacket C, with a steam inlet at D and a tap for condensed water at E. F is the cock by which the solution is drawn off.

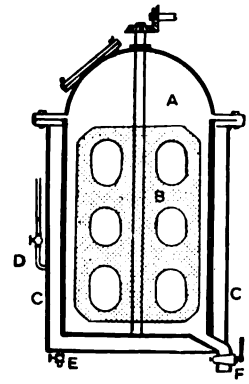

FIG. 4.

After the rubber is dissolved, about 12 to 24 per cent. of sulphur is added, and

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thoroughly incorporated with the solution. The sulphur may be in the form of chloride of sulphur, or as sulphur pure and simple. A very small quantity of sulphur is required to give the necessary result, 2 to 3 per cent. being sufficient to effect vulcanisation; but a large quantity is always added to hasten the operation.

Even after prolonged treatment with the two solvents, a solution of uniform consistency is never obtained: clots of a thicker nature will be found floating in the solution, and the next operation is to knead it up so as to obtain equal density throughout. Fig. 5 will give an idea of how this mixing is done.

At the top of a closed wooden chamber is a covered reservoir A, containing the solution of rubber. A long slit at the base of this reservoir allows the solution to fall between sets of metal rollers, BBB, below. Neighbouring rollers are revolving in opposite directions, and at different speeds, so that, after passing all three sets of rollers, and emerging at the bottom, the solution should be of uniform consistency. CCC are the guiding funnels, and EE are scrapers to clear the solution from the rollers. D is a wedge-shaped plug worked by a rack and pinion, and regulates the flow of the solution.

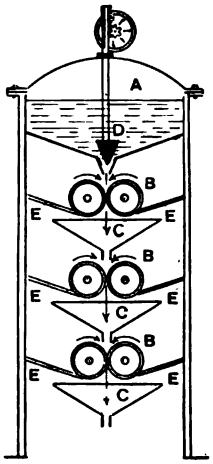

FIG. 5.

It now remains to apply the rubber to the fabric and vulcanise it. Up to this stage the sulphur has only been mechanically mixed with the rubber: the aid of heat is now required to bring about chemical combination between the two. This process, which is known as "burning," consists in subjecting the rubber-covered fabric to a temperature of about 120° C. Sulphur itself melts at 115° C., and the temperature at which combination takes place must be above this. Fig. 6 shows one of the methods of spreading the rubber on the cloth. A is the tank containing the solution, with an outlet at the bottom arranged so as to regulate the flow of solution. The fabric passes slowly underneath this, receiving as it travels a thin coating of the waterproofing. The two rollers at B press the solution into the fabric and distribute the proofing evenly over the entire surface.

After leaving the two squeezing rollers, the cloth travels slowly through a covered chamber C, having a series of steam pipes EE underneath, to evaporate the solvent: this condenses on the upper portion of the

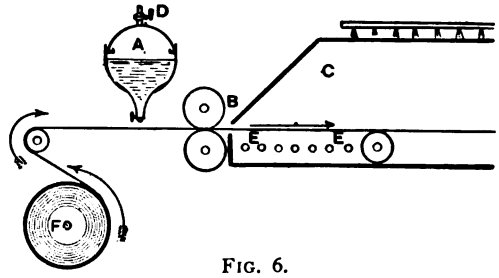

FIG. 6.

chamber, which is kept cooled, and flows down the sides into suitable receptacles. After this the proofed cloth is vulcanised by passing round metal cylinders heated to the necessary temperature, or by passing through a heated chamber. Fig. 7 shows the spreading of rubber between two fabrics. The two cloths are wound evenly on the rollers BB; from this they are drawn conjointly through the rollers D; the stream of proofing solution flowing down between the rollers, which then press the two fabrics together with the rubber inside. The lower rollers marked CC are heated to the necessary degree, and cause the rubber and sulphur to combine in chemical union.

So far the operation of proofing has been described as though pure rubber only was used; in practice the rubber forms only a small percentage of the proofing material, its place being taken by cheaper bodies. One of the common ingredients of proofing mixtures is boiled linseed oil, together with a small quantity of litharge; this dries very quickly, and forms a glassy, flexible film. Coal-tar, shellac, colophony, etc., are all used, together with india-rubber varnish, to make different waterproof compositions. Oil of turpentine and benzol form good solvents for rubber, but it is absolutely essential that

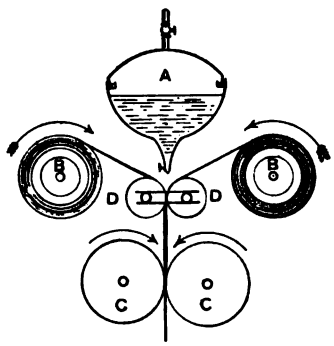

FIG. 7.

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both rubber and solvent are perfectly anhydrous before mixing. Oil of turpentine, alcohol, etc., can be best deprived of water by mixing with either sulphuric acid or dehydrated copper sulphate, and allowing to stand. The acid or the copper salt will absorb the water and sink to the bottom, leaving a supernatent layer of dehydrated turpentine or whatever solvent is used. All the sulphur in a rubber-proofed cloth is not in combination with the rubber: it is frequently found that, after a lapse of time, rubber-proofed material shows an efflorescence of sulphur on the surface, due to excess of sulphur, and occasionally the fabric becomes stiff and the proofing scales off. Whenever a large proportion of sulphur is present, there is always the danger of the rubber forming slowly into the hard vulcanite state, as the substance commonly called vulcanite consists only of ordinary vulcanised rubber carried a stage further by more sulphur being used and extra heat applied. If, after vulcanising, rubber is treated with caustic soda, all this superfluous sulphur can be extracted; if it is then well washed, the rubber will retain its elasticity for a long period. With the old methods of proofing, a sheet of vulcanised rubber was cemented to a fabric with rubber varnish, and frequently this desulphurising was performed before cementing together. The result was a flexible and durable cloth, but of great weight and thickness, and expensive to produce.

The chemistry of rubber is very little understood; as mentioned previously, rubber is a highly complex body, liable to go through many changes. These changes are likely to be greater in rubber varnish, consisting of half-a-dozen or more ingredients, than in the case of rubber alone. The action of sunlight has a powerful effect on rubber, much to its detriment, and appears to increase its tendency to oxidise. Vulcanised rubber keeps its properties better under water than when exposed to the air, and changes more slowly if kept away from the light. It appears as though a slight decomposition always takes place even with pure rubber; but the presence of so many differently constituted substances as sometimes occur in rubber solutions no doubt makes things worse. Whenever a number of different bodies with varying properties are consolidated together by heat, as in the case of rubber compositions, it is only reasonable to expect there will be some molecular re-arrangement going on in the mass; and this can be assigned as the reason why some proofings last as long again as others. Some metallic salts have a very injurious action on rubber, one of the worst being copper sulphate. Dyers are frequently warned that goods for rubber proofing must be free from this metal, as its action on rubber is very powerful, though but little understood. As is generally known, grease in any form is exceedingly destructive to rubber, and it should never be allowed in contact in the smallest proportion. Some compositions are made up by dissolving rubber in turpentine and coal-tar; but in this case some of the rubber's most valuable properties are destroyed, and it is doubtful if it can be properly vulcanised. Owing to rubber being a bad conductor of heat, it requires considerable care to vulcanise it in any thickness. A high degree of heat applied during a short period would tend to form a layer of hard vulcanite on the surface, while that immediately below would be softer and would gradually merge into raw rubber in the centre.

The different brands of rubber vary so much, especially with regard to solubility, that it is always advisable to treat each brand by itself, and not to make a solution of two or more kinds. Oilskins and tarpaulins, etc., are mostly proofed by boiled linseed oil, with or without thickening bodies added. They are not of sufficient interest to enlarge upon in this article, so the second, or "water repellent" class, has now to be dealt with.

All the shower-proof fabrics come under this heading, as well as every cloth which is pervious to air and repulsive to water. The most time-honoured recipe for proofing woollen goods is a mixture of sugar of lead and alum, and dates back hundreds of years. The system of using this is as follows: The two ingredients are dissolved separately, and the solutions mixed together. A mutual decomposition results, the base of the lead salt uniting with the sulphuric acid out of the alum to form lead sulphate, which precipitates to the bottom. The clear solution contains alumina in the form of acetate, and this supplies the proofing quality to the fabric. It is applied in a form of machine shown in Fig. 8, which will be seen to consist of a trough containing the proofing solution C, with a pair of squeezing rollers AA over the top. The fabric is drawn down through the solution and up through the squeezers in the direction of the arrows. At the back of the machine the cloth automatically winds itself on to a roll B, and then only requires drying to develop the water-resisting power. C is a weight

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acting on a lever which presses the two rollers A,A together. The water-repelling property is gained as follows:

Drying the fabric, which is impregnated with acetate of alumina, drives off some of the volatile acetic acid, leaving a film of

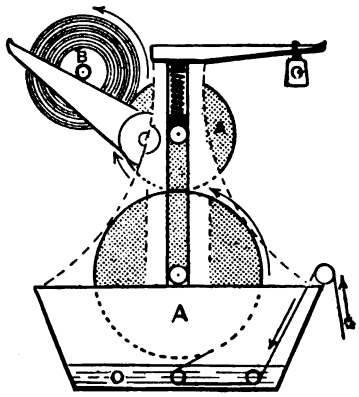

FIG. 8.

basic acetate of alumina on *each wool fibre.* This basic salt is very difficult to wet, and has so little attraction for moisture that in a shower of rain the drops remain in a spheroidal state, and fall off. In a strong wind, or under pressure, water eventually penetrates through fabrics proofed in this manner: but they will effectually resist a sharp shower. Unfortunately, shower-proofed goods, with wear, gradually lose this property of repelling water. The equation representing the change between alum and sugar of lead is given below. In the case of common alum there would, of course, be potassium acetate in solution besides the alumina.

Alum. Sugar of lead.

$$Al_2K_2(So_4)_4 + 4Pb(C_2H_3O_2)_2$$

Lead sulphate. Potassium acetate. Aluminium acetate.

$$= 4PbSo_4 + 2KC_2H_3O_2 + Al_2(C_2H_3O_2)_6$$

Now that sulphate of alumina is in common use, alum need not be used, as the potash in it serves no purpose in proofing.

There are many compositions conferring water-resisting powers upon textiles, but unfortunately they either affect the general handle of the material and make it stiff, or they stain and discolour it, which is equally bad. A large range of waterproof compositions can be got by using stearates of the metals; these, in nearly every case, are insoluble bodies, and when deposited in the interior of a fabric form a water-resisting "filling" which is very effective. As a rule these stearates are deposited on the material by means of double baths; for example, by passing the fabric through (say) a bath of aluminium acetate, and then, after squeezing out the excess of liquid, passing it through a bath of soap. The aluminium salt on the fabric decomposes the soap, resulting in a deposit of insoluble stearate of alumina. This system of proofing in two baths is cleaner and more economical than adding all the ingredients together, as the stearate formed is just where it is required "*on the fibres*," and not at the bottom of the bath.

One of the most important patents now worked for waterproofing purposes is on the lines of the old alumina process. In this case the factor used is resin, dissolved in a very large bulk of petroleum spirit. The fabrics to be proofed (usually dress materials) are passed through a bath of this solution, and carefully dried to drive off the solvent. Following this, the goods are treated by pressing with hot polished metal rollers. This last process melts the small quantity of resin, which is deposited on the cloth, and leaves each single fibre with an exceedingly thin film of resin on it. It will be understood that only a very attenuated solution of resin is permissible, so that the *fibres* of the threads and *not* the threads themselves are coated with it. If the solution contains too much resin the fabric is stiffened, and the threads cemented together; whereas if used at the correct strength (or, rather, weakness) neither fabric nor dye suffers, and there is no evidence of stickiness of any description.

Fig. 9 shows a machine used for spreading a coat of either proofing or any other fluid on one side of the fabric. This is done by means of a roller A running in the proofing

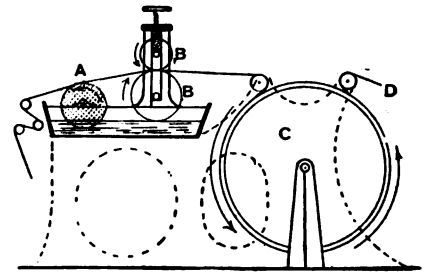

FIG. 9.

solution, the material to be coated travelling slowly over the top and just in contact with the roller A, which transfers the proofing to it. Should the solution used be of a thick nature, then a smooth metal roller will transfer sufficient to the fabric. If the

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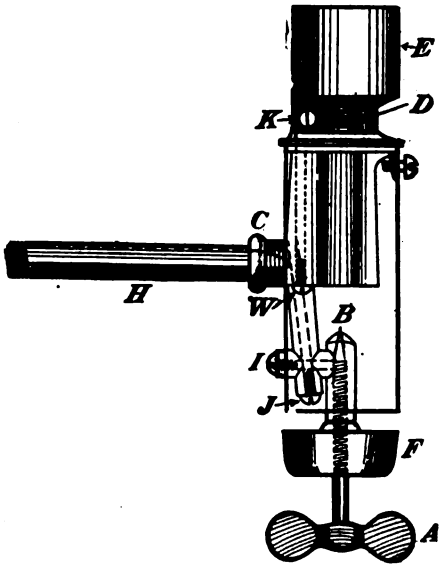
reverse is the case, and the liquid used is very thin, then the roller is covered with felt, which very materially adds to its carrying power. As shown in Fig. 9, after leaving the two squeezing rollers B,B, the fabric passes slowly round a large steam-heated cylinder C, with the coated side uppermost. This dries the proofing and fastens it, and the cloth is taken off at D.

Besides stearates of the metals, glues and gelatines have been used for proofing purposes, but owing to their stiffening effect, they are only of use in some few isolated cases. With glue and gelatine the fixing agent is either tannic acid or some metallic salt. Tannic acid converts gelatine into an insoluble leather-like body: this can be deposited in the interstices of the fabric by passing the latter through a gelatine bath first, and then squeezing and passing through the tannic acid. Bichromate of potash also possesses the property of fixing the proteid bodies and rendering them insoluble.

A GASOLINE INCANDESCENT LAMP.

THE high luminous efficiency of the incandescent gas burner is now fully recognised, and many efforts have been made to produce an oil lamp which can utilise an incandescent mantle. The accompanying figure represents the burner of the "Sun" Incandescent Lamp, made by the "Sun" Light Co., 143, Holborn, E.C. This lamp burns 74-degree deodorised stove gasoline, contained in a brass reservoir (not shown in the figure) which is in communication with the tube H through a supply valve (also not shown). The lamp is designed so that the gasoline evaporates from the pin-hole jet B, and then ascends through the tube above it, and burns at the burner-head E. A mantle, similar to those used in gas lighting, is suspended above the burner-head. In order to secure a non-luminous smokeless flame at the highest possible temperature, air is drawn in through the apertures D, just as in a Bunsen burner. The procedure of lighting the lamp is as follows:—The supply of gasoline is cut off by closing the supply valve, the drip cup F is filled with methylated spirit, and this is ignited; by this means the temperature of the jet B and the surrounding tubes is raised to a point at which gasoline will readily vaporise. When the spirit has been burnt out, the supply valve is opened and the gasoline is admitted to the pin-hole jet B, where it at once vaporises and ascends to the burner-head E. The mixture of air and gasoline vapour is ignited at the top of the glass chimney as in an incandescent gas burner. The tube H is stuffed with cotton-wool, which prevents any sudden rush of the liquid gasoline: a wire gauze protector at C prevents this wool from getting into the



burner-tube. The needle valve at B is opened or closed by turning the thumb-screw A; this valve is not used for regulating the flame, but merely for cleaning the pinhole jet B.

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THE FIBROUS CONSTITUENTS OF PAPER.

(Continued.)

By CLAYTON BEADLE.

Illustrated with Photo-micrographs by John Christie, F.R.M.S. Diagrams by the Author.

IT is impossible to describe or to illustrate by means of diagrams the exact manner in which a vatman dips the mould into the vat, nor is it an easy matter to illustrate in any way the motion of the fibres due to the agitation of the stuff in the vat. This latter I shall deal with first.

The paper-maker's vat is agitated by means of a revolving fan or screw placed near the bottom of the vat. The sides of the vat are sloping. The effect of the agitation is to cause currents to pass vertically upwards and to separate over the surface, somewhat in the manner of the welling up of a spring out of the earth; or perhaps, more correctly, as a spring wells up at the bottom of a river through the water and reaches the surface, producing whirls, which are familiar to everybody. This motion has a peculiar significance. The fibres tend to point in the directions in which the currents flow.

The way the fibres are placed in the liquid at the time the vatman dips his mould into the stuff has considerable after effect upon the sheet. Some vatmen declare that "the paper is made in the vat," meaning that the mode of agitation produced in the vat largely affects the after results.

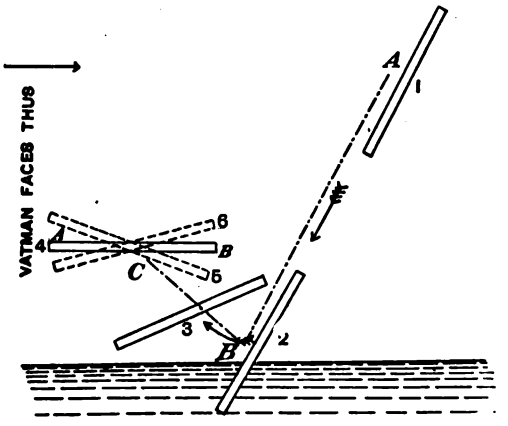

FIG. 2.—SIDE VIEW, SHOWING MODE OF DIPPING DECKLE INTO VAT.

A B C, path of vatman's thumb.
A, front deckle edge. *B, back deckle edge.*

FIG. 1.—TRANSVERSE SECTION IN "B" DIRECTION OF STRONGEST HAND-MADE PURE LINEN PAPER, 30 LBS. MEDIUM.
Magnified 325 diameters.
Showing freedom from air-spaces as compared with very thick paper of same make, illustrated in Fig. 7, p. 255 (TECHNICS, No. 9, September, 1904).

I have also heard it said that you can see "watermarks" in the stuff, meaning that you can see distinct direction and disposition of fibres in the stuff, due to the agitation.

Now let us form some conception of the manner in which the mould is dipped into the vat: Fig. 2 is intended to roughly demonstrate this. The mould is first held in front of the vatman, with its longer side horizontal, and grasped between the fingers and the thumbs, with the thumbs uppermost, and held at an angle of about 120, as shown in the diagram. The line *A B C* is intended to show the travel of the thumbs of the vatman. A is what would be called the near side, or front deckle edge; B is the far side, or back deckle edge. The first position is as shown at 1. The mould is then lowered so as to be partially immersed in the liquid, as shown at 2. It is then raised, so that

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one-half to one-third of the mould only has been allowed to dip under the surface of the stuff. Whilst the mould is being raised, it is at the same time brought to a horizontal position. When it reaches the position 4, it has reached a convenient height for the vatman to give it the necessary side-shake, to which reference has already been made on Fig. 6, page 347*; it rapidly passes the horizontal position and is tilted towards direction 5, which not only brings the stuff to the far deckle edge, but also whisks the surplus back into the vat. It is here that the vatman has to display his skill in retaining on the mould just sufficient material to make the sheet of necessary thickness and substance. The mould is then brought back somewhat past its horizontal position, then brought to the horizontal position, when it receives the side shakes. This rocking, as we may so describe it, is an important factor in the distribution of fibres.

Next, the side-to-side shakes are given, and if we look down upon the operation from above we can see that the side shakes, in addition to producing waves in the direction of the shake, induce waves at right angles to these simultaneously. Why this should be it is not easy to explain. The stuff up to this period has an "angry" or "hungry" look; it is gaping open, and has a sort of flocculent, cloudy appearance: the final operations, about to be described, suddenly change its appearance into that of a closed, well-compacted sheet. The vatman raises and lowers the mould bodily; that is, he gives it the same sort of motion as is produced with a jog strainer (a sort of up-and-down shake), and simultaneously with this a rocking motion. This rocking motion is an important factor in the distribution and final interlacing of the fibres.

All this sounds extremely complex, and one would judge that it must be a very long operation; but the process is done at an extremely rapid rate, several sheets a minute being produced. I have described these operations somewhat in detail, in order to trace their effects upon the finished sheet.

It will be noticed that the near deckle edge at A is not worked under the same conditions as the far deckle edge at B. A is dragged through the stuff, and B receives its stuff by the inclination of the mould, or by a rush of the material across the mould. It is not, strictly speaking, correct to say that the various operations of shaking, lifting, inclining the mould, etc., are done at distinct intervals; they more or less dovetail into one another. Some men claim that they can tell the difference between the near deckle edge and the far deckle edge with their eyes shut, by taking up the paper and tearing it: this is no exaggeration, although a good deal of experience is required. I have myself done this repeatedly, especially on papers where there is a marked difference between the two edges. If a sheet of paper is torn close to the deckle edge A and parallel to it, by holding the sheet in the left hand and slowly and gently tearing down a narrow riband of the paper between the finger and thumb of the right hand, a wide tear will be produced. If the same operation is performed close to the deckle edge B the stuff will tear "short," and the width of the tear will be only slight. This is easy enough for one to appreciate when looking at it, but there is something indescribable about the "feel" of the tear between the two: with a certain amount of practice, even with one's eyes shut, a distinct difference can be noticed.

I thought it worth while to examine the physical qualities of the paper close to the deckle edge A and close to the deckle edge B, in the hope that I could find some explanation. I did this on a paper marked Y on Fig. 3, the results of which are shown on Fig. 4, both in regard to strength and elongation at the time of fracture.

CLOSE TO BACK DECKLE EDGE B.

Strips cut parallel to B.		Strips cut at right angles to B.	
Strength. lbs. per inch.	Elongation.	Strength. lbs. per inch.	Elongation.
(1) 34·9	9·4%	(4) 37·2	7·6%
(2) 30·5	8·4%	(5) 36·2	7·0%
(3) 29·0	7·0%		
Mean 31·5	8·3%	Mean 36·7	7·3%

	Strength.	Elongation.
Mean of both the above	34·1	7·8%

CLOSE TO FRONT DECKLE EDGE A.

Strips cut parallel to		Strips at right angles to	
Strength. lbs. per inch.	Elongation.	Strength lbs. per inch.	Elongation.
(1) 37·3	8·0%	(4) 40·2	6·8%
(2) 35·2	8·2%	(5) 37·7	6·8%
(3) 35·2	8·2%		
Mean 35·9	8·1%	Mean 39·0	6·8%

Mean of both the above	37·45	7·95%
Mean of front and back	35·77	7·87%

* TECHNICS, Vol. II., No. 10, October, 1904.

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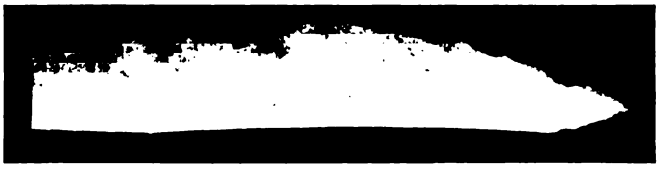
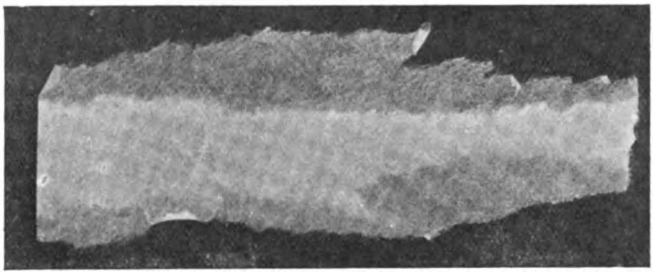
Paper "Y." *Torn close to far deckle edge* B. (Fig. 2.)

Paper "X." *Torn close to far deckle edge* B.



Paper "Y." *Torn close to near deckle edge* A.



Paper "X." *Torn close to near deckle edge* A.

FIG. 3.—TO ILLUSTRATE NATURE OF TEAR CLOSE TO NEAR AND FAR DECKLE EDGES.

On examining the foregoing figures it will be noticed that the front deckle edge, which gives the wide tear, is the strongest in both directions, and shows greater uniformity in strength (the difference in the strength of the two directions being only 8·6 per cent.); and, furthermore, the paper close to the front deckle edge is considerably stronger than that close to the back deckle edge. In the above case the strips cut parallel to the deckle edge show the paper to be nearly 14 per cent. stronger in the front, and the strips cut at right angles to the deckle edge show the paper to be over 6 per cent. stronger in the front, which is in both cases the strongest way of the sheet.

It is obvious why the paper tears with a more fibrous and wider edge close to the front deckle edge, as it is at this part of the paper that the fibres are mostly pointing in a direction at right angles to the tear. The great difference between the two tears can only be accounted for by a much better felting in the front. When fibres are pointing in a line with the direction in which you want to tear, the paper has a tendency to tear "short." Taking the average of both ways of the sheet, for the front and for the back, the front is 10 per cent. stronger than the back, and the fact of it being more uniform in strength in different directions indicates that it is better felted.

As we would expect, the figures for the elongation vary in an inverse order, but in a less degree. The back deckle edge is $3\frac{1}{2}$ per cent. greater in stretch in one direction, and 7·3 in the other direction.

Thus it will be seen that hand-made paper is, from many points of view, by no means a uniform product. Nevertheless, in spite of these irregularities, its average physical qualities are higher and better than those of machine-made paper; and, as a consequence, the manufacture of hand-made paper is still carried on very extensively in this country and on the continent, although it is not practised in the United States or Canada;

STRENGTH RATIOS.

Deckle edge.

	Back.	Front.			
Parallel . .	31·5	: 35·9	::	100	: 113·9
Right angles	36·7	: 39·0	::	100	: 106·3
Mean . .	34·1	: 37·45	::	100	: 110·1

BACK DECKLE:

Strips parallel to, 31·5 — Strips at right angles to, 36·7

100 : 116·5

FRONT DECKLE:

Strips parallel to, 35·9 — Strips at right angles to, 39·0

100 : 108·6

ELONGATION RATIOS OF FOREGOING.

Front.	Back.			
8·1	: 8·3	::	100	: 103 5
6·8	: 7·3	::	100	: 107·3
	Mean ratio . .			105·4

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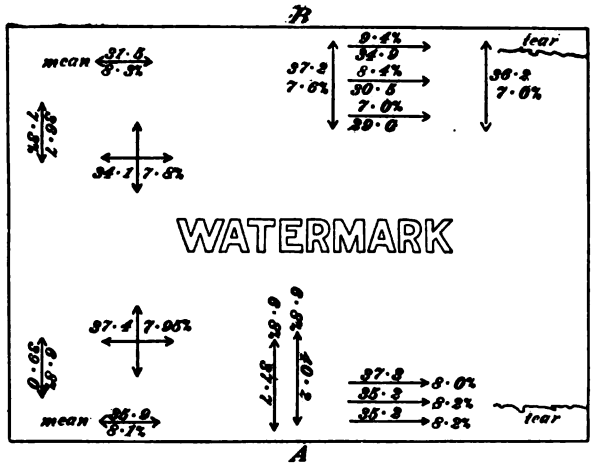

FIG. 4.—SHOWING RESULTS OF PHYSICAL TESTS OF PAPER, PERFORMED CLOSE TO FAR (B) AND NEAR (A) DECKLE EDGES.

these countries appear to rely almost entirely upon the importation of the English products.

Now that we have briefly considered on general principles the forces which operate in the manufacture of hand-made papers, and the effects which the same have upon the micro-structure, we shall make an attempt in the same direction as regards machine-made papers. With the latter there is something which corresponds to the wave produced in hand-made papers on taking the mould out of the vat. This something is the rush of the stuff in a quick stream under the "slices" on to the machine wire. This rush is frequently at a greater rate than the travel of the wire. The travel of machine wire and rush of stuff are in one and the same direction. Those fibres that are in immediate contact with the machine wire, when first the stuff meets the latter on the wet end of the paper machine, are of course the first to settle; and the water in which they had been suspended drains through the machine-wire into the "save-all." Immediately these fibres become stranded they take up their positions once and for all; they can no longer be moved by the action of the "shake," and are stranded as effectually as a ship on a sand-bank at an ebb tide. Further along the wire another layer of fibres is stranded on the top of the first layer. This second layer is less affected by the inrush of the stuff under the slices, but still has to contend with the effects of the motion of the machine itself, which of course is in the machine direction. These two influences, *viz.*, the inrush of the stuff and the travel of the machine, both tend to set the fibres in the machine direction. With very rapid running machines, such as those used for the manufacture of "news," travelling at the rate of four or five hundred feet per minute, the stuff at one end of the slices may have a head of three or four inches. This head would cause a flow under the slice proportionate not only to the head (or difference in level on the two sides of the slice), but also of course to the width of the gap under the slice (*i.e.*, the distance of the bottom edge of the slice from the surface of the machine wire). The raising and lowering of the slice or slices (sometimes there are several, seldom less than two) affords a means of control to the machine man. The rush of the stuff is not only influenced by the above-mentioned causes, but with very high-speed machines is greatly augmented by the machine wire itself; by means of its texture this offers great friction to the liquid, and in its rapid travel past the narrow gap of the slices draws a lot of stuff through. This is a condition which prevails with very fast running machines, so much so that the strength in the machine direction, due to the prevailing position of the fibres, is often *three* times, and not infrequently *ten*, times the strength in the cross direction. In extreme cases of fast running we have therefore a strength ratio of "machine" to "cross" direction of $\frac{100}{10}$; whereas in machine-made high-class writing papers, where the speed of the machine is perhaps only one-tenth of the above, or say 40 to 50 feet per minute, the ratio is $\frac{100}{60}$. This shows the great difference produced by the speed of paper machines.

This extreme weakness imparted to paper when pulled in the cross direction, as the result of the high speed of paper machines, is not of much consequence in the manufacture of "news," where the strength is required mostly in the machine direction, as the paper is handled in rotary printing machines in the reel, where the pull is exerted only in the machine direction. Now in the case of higher-class machine-made papers, taking common wrappings as the bottom and strong banks as the top of the ladder, it is necessary that the paper should have strength in both directions, or more correctly, in all directions. Just as the strength of a chain is that of its weakest link, so, for most industrial purposes, the strength of a paper is that of its weakest direction.

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With papers of any given composition of fibres, by increasing the speed of the machine you increase the strength in the machine direction, but you do so at the expense of the cross direction; and so far as my observations go, this increase is exerted in such a ratio that the mean figure of the two directions is a constant. (This is true, at any rate, for certain classes of paper.)

To obviate this unfortunate tendency of machine-made papers, the "wet-end" is provided with a "stake" to imitate the shake given to the hand mould by the vatman. The end where the stuff passes on to the wire receives the greatest amount of shake, and the shake diminishes down to nothing at the fulcrum situated close to the suction boxes. The "shake" is generally actuated by means of a crank close to the breast-roll. The shake has to come to a dead standstill before it reaches the "suction boxes" and the "couch roll." When a shake is actuated by means of a crank, its velocity varies in the same way as a piston in a steam cylinder, being greatest midway between the two extremities, and diminishing gradually as it reaches either end of the stroke. The vatman, on the other hand, shakes his mould vigorously, coming to the end of his shake with a vigorous jerk. This jerk and return should be more effective in setting the fibres right than the shake given to a paper machine by means of a crank motion. The second important difference between the shake of the hand mould and that of a paper machine is this—the vatman, in a large measure, does one thing at a time, shaking either from side to side, or backwards and forwards; he cannot do these two things simultaneously. With a paper machine, whilst the shake is operating, the machine wire is travelling forward at a uniform speed. The result is that the actual path of the fibres composing the pulp resembles that of a serpent travelling along the ground (or as the serpent is depicted), the convolutions being greatest at the breast-roll end, and diminishing to nothing at the two fulcrums. The number of these convolutions would depend upon the ratio of the period of the shake, to the time which the machine wire takes to travel from one end of the machine to the other. Thus, if a complete shake took one-third of a second, and the wire took 30 seconds in its travel, there would be 90 convolutions in the curve. The stuff would then be shaken 90 times in its passage along the machine. The shake of the paper machine has one advantage: its maximum amplitude is exerted where it is most required—that is, at the end where the fibres are most in suspension, and settling at the greatest possible rate. Fig. 5 is intended to exemplify in diagrammatic form the actual path of the fibres.

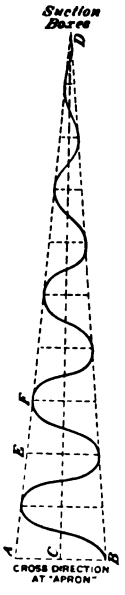

FIG. 5.—CURVED LINE SHOWING PATH OF PULP AS IT TRAVELS ALONG WET END OF MACHINE.

A D, *limit of left-hand shake.*
B D, *limit of right-hand shake.*
C D, *machine direction.*
E F, *distance travelled during shake period.*

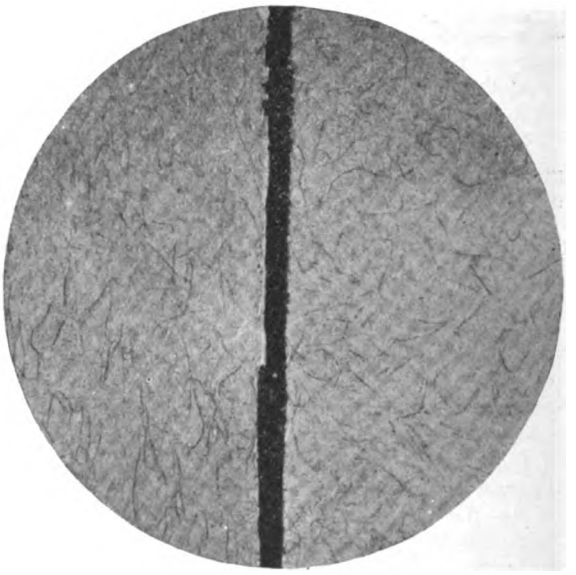

FIG. 6.—MOTTLED PAPER, SHOWING DIRECTION OF COLOURED FIBRES ON BOTH SURFACES.

Magnified 2·5 diameters.

"Wire" or under surface to left, top surface to right. Tear in machine direction.

There is some considerable difference between the arrangement of the fibres which first settle on the machine wire (*i.e.*, those which constitute the under-side of a sheet of machine-made paper), and that of the fibres which settle later (*i.e.*, those which constitute

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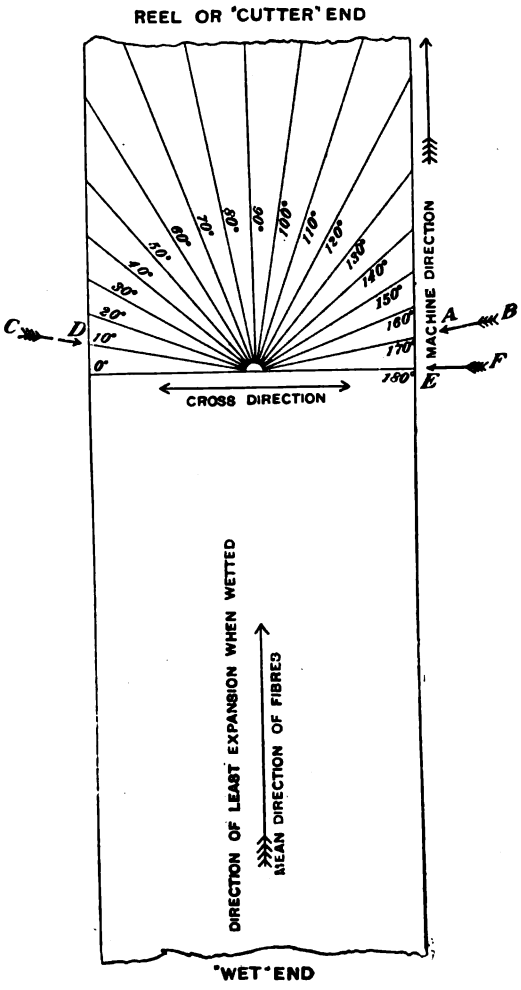

FIG. 7.—BIRD'S-EYE VIEW OF WEB OF PAPER ON MACHINE.

Least strength when pulled, and greatest strength when torn in directions A B, C D.
Greatest strength when pulled in machine direction.
Greatest expansion when wetted, and greatest elongation when pulled, in direction E F.

the top surface). We should rather expect to find that the under side would consist more of fibres pointing in the machine direction than the top side, especially on fast-running machines. In this case, when the travel of the wire has overcome the inertia of the stuff which it carries (*i.e.*, when the stuff is travelling on, and at the same speed as, the wire), the forward travel of the wire no longer exerts an effect in causing the fibres to point in the machine direction, but the shake is still exerting its influence, only in a diminishing ratio. This is not the condition of affairs that prevailed when the stuff first touched the machine wire, and we should, therefore, expect as a consequence that the direction of the fibres would be different, and more or less disposed in layers. This is well exemplified in Fig. 6, photographed from a disc of paper, prepared by Mr. R. W. Sindall. The whole matter is extremely complex and difficult to investigate, because the paper machine is run at every conceivable speed within its limits; the length, as well as the amplitude of the shake is under control, and altered to suit various requirements; also the amount of water in the stuff on the machine wire is varied. If the water quickly passes through, all the fibres may be stranded long before the shake has had its maximum effect; whereas if there is water keeping some of the fibres in suspension, the shake can have its maximum effect. Undoubtedly also the thickness of the sheet influences the distribution of the fibres. As the deckle edge sways to and fro, due to the crank motion of the stake, each time that it comes toward the centre of the machine, it creates a wave or ripple (see Fig. 8), the right-hand side creates a right-handed wave, and the left hand a left-handed wave. These waves are produced by the edge of the deckle on either side describing a small arc of a large circle. The waves are not such as would be produced in still water, because they are produced in a

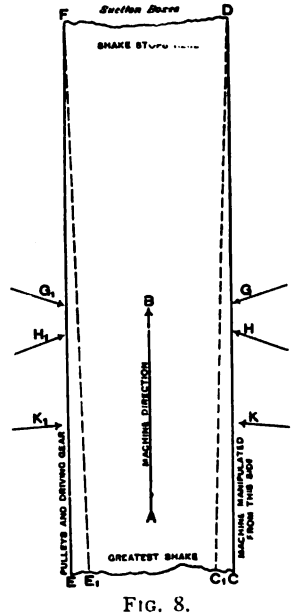

FIG. 8.

TO ILLUSTRATE FORCES ACTING ON WEB OF PAPER, WHEN PASSING OVER "WET END" OF MACHINE.

F, D, *fulcra.* C D, E F, *deckle edges.*
C_1D, E_1 F, *waves due to left and right-hand shakes respectively.*
K, K_1, *directions of waves due to shakes.*
H, G, H_1, G_1, *directions of minimum strength when pulled.*
A, B, *direction given to fibres by forward rush of stuff and motion of machine wire. Also direction of greatest strength and least elongation when pulled.*

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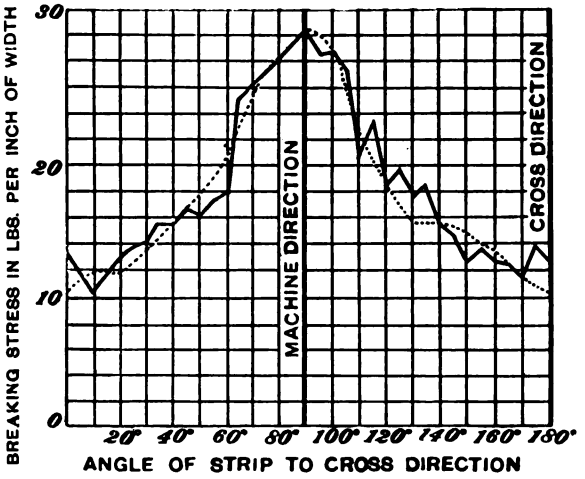

FIG. 9.—CURVES SHOWING BREAKING STRESS OF PAPER IN DIFFERENT DIRECTIONS.

Machine-made tub sized cream-wove extra superfine note paper, made from cotton and linen rags.

The line . . . . . shows the results of tests taken for each 10°, *and the line ——— for each* 5°. *Cross direction* 0° *or* 180°; *machine direction* 90°.

current that is flowing at a rapid rate. These ripples would tend to set the fibres in the direction in which the ripples travel. To what extent these exert an influence it is difficult to say. I am disposed to think they are of minor importance, but they correspond in a small measure with the ripples produced by the deckles of the hand mould when shaken.

Let us carefully examine Fig. 9, showing the strength of machine-made papers at different angles of pull every five degrees. I have frequently noticed that the minimum strength, as with the above, is not exactly in the cross direction, but that it lies somewhere between 0° and 10°. The dotted line in Fig. 9 shows the strength of a paper at different angles when tested every 10 degrees. The smallest strength is here in the cross direction, but frequently (more frequently than not, as far as my experience goes) this is not the case, as is shown in the zig-zag line where a paper is tested for strength every 5 degrees. It will be noticed, however, that in both papers the greatest strength is in the machine direction. The maximum strength appears always to be in the machine direction: that is, if a sufficient number of tests are made in each direction, and the average taken. It is somewhat difficult to account for the zig-zag course of the curve for the sample tested every 5 degrees. All samples so far examined, tested every 5 degrees, show this peculiarity, not discernible when tested every 10 degrees. The minimum is at an angle of a few degrees to the cross direction instead of coincident with it, which leads me to believe that it is in some way connected with the shake (which is exerted at a slight angle to the cross direction), and also with the ripple produced by the deckles. It appears that the direction of least strength when pulled is coincident with what we may describe as the "effective direction" of the shake, giving rise to papers which are of least strength at a small angle to the cross direction. As these forces are exerted equally on either side of the machine direction, they do not tend to alter the direction of greatest strength, which would naturally lie in the machine direction, as I have found to be the case without exception.

We have previously noted that, when a number of strips are cut side by side and parallel to each other, on a tub-sized cream-wove writing paper about 27 lbs. L.P., at times the tests show wonderful

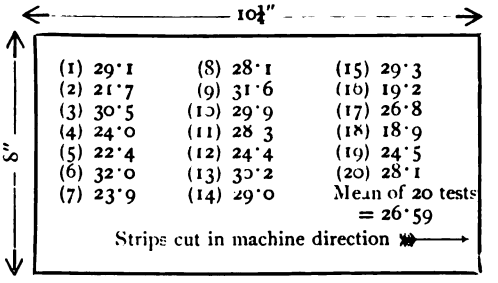

FIG. 10.

TO ILLUSTRATE FLUCTUATIONS IN STRENGTH WHEN ALL STRIPS ARE CUT PARALLEL.

This is a machine-made thin Linen Bank, showing considerable fluctuation.

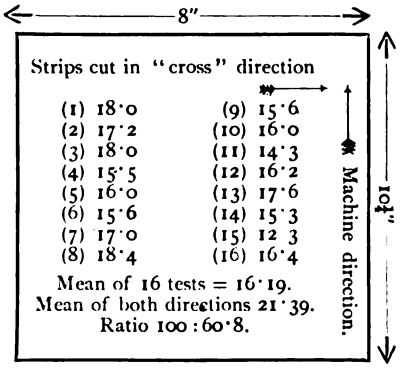

FIG. 11.

Same as Fig. 10, but in Cross direction. In this direction the paper shows greater regularity.

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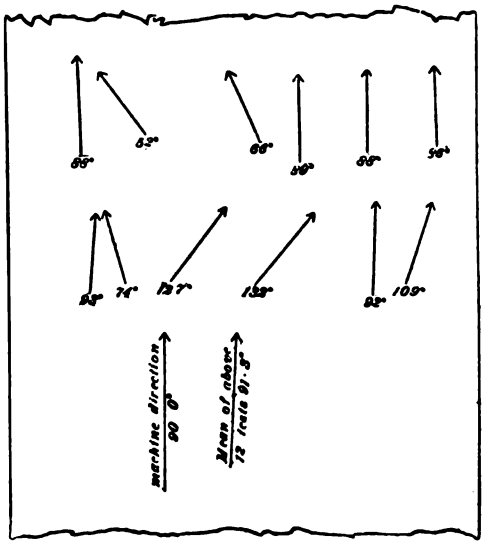

FIG. 12.—Showing great local variation in the direction of least expansion, when wetted at different parts of web of machine-made paper; mean of tests coincides with machine direction.

regularity, whether cut in the machine or cross directions, whether waterleaf or tub-sized. In such a paper there is little or no local variation in different parts of the web; but with a thin, strong paper such as 10 lbs. L.P., either sized or unsized, there is considerable local variation in strength.

Fig. 10 shows the results of a number of tests on strips cut parallel to one another in the machine direction, and Fig. 11 a similar sheet cut in the cross direction. This was the strongest thin linen bank that I could procure. In each case as many strips were cut out as the sheet would yield, *viz.*, 20 in one direction and 16 in the other. It will be noticed that in the machine direction the tests vary between 18·9 and 32·0, a very large variation; the mean of the 20 figures being 26·59. I tested this paper with a view of ascertaining whether it would give a higher strength per unit of sectional area than the thicker linen papers to which reference has been made in the article* under "Linen," but I found that in this respect it was inferior to a paper of about double the substance, where a maximum is obtained; after which, with very thick papers, the strength per unit of sectional area diminishes. Fig. 11 shows a greater regularity in individual tests, although there is considerable variation, the extremes being 12·3 and 18·4, the mean figure being 16·19. It would appear, therefore, that a very strong machine-made linen bank is liable to considerable local variation in strength, as shown on strips one inch wide, and that the amount of variation is greater when pulled in the machine direction than in the cross direction.

The next matter we have to consider is the local variation in respect of the direction of least expansion when wetted. As previously explained in regard to hand-made papers, there is little local variation on discs of the diameter of a penny, as regards different parts of any one individual sheet; each individual sheet has a constant of its own, as a result of the manner in which the vat-man shook the sheet together. Thus in one sheet we found a mean angle of 72 degrees, in another of similar make an angle of 99·1 degrees, etc. With machine-made papers we have a very different state of affairs: the forces acting upon the web remain constant (or should do so) throughout the whole make, but nevertheless there is very considerable local variation, as is shown on Fig. 12, the maximum figure being 132 degrees and the minimum figure 52 degrees; nevertheless the mean of 12 tests show 91·3 degrees, or an angle of only 1·3 degrees to the machine direction. Thinking this might be a mere accident, I made 30 determinations and took the average, and in all about a hundred determinations of the least expansion when wetted by the disc method on other papers. The average figure in each case was within two or three degrees of the machine direction, the average of some within a fraction of a degree. These slight differences are within the region of experimental error. As a result of these various determinations, we are safe in asserting that the direction of least expansion when wetted, the direction of greatest strength, and the mean direction of the fibres, are all coincident with the machine direction.

* TECHNICS, Vol. II., No. 9, September, 1904, pp. 251–256.

(To be continued.)

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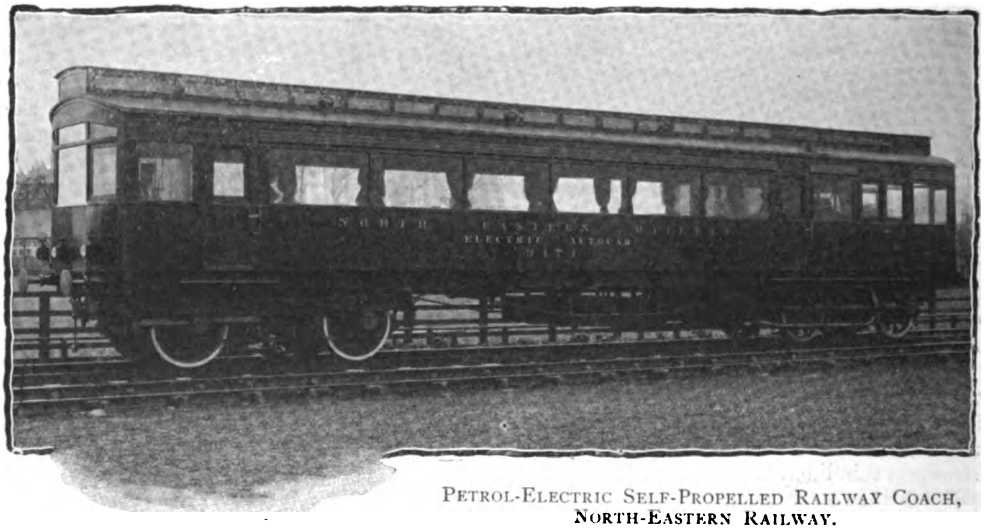
PETROL-ELECTRIC SELF-PROPELLED RAILWAY COACHES.

THE accompanying illustration represents one of the petrol-electric railway coaches recently introduced on the North-Eastern Railway. A notice respecting these cars has already been published in TECHNICS;* it will be remembered that each coach contains a petrol engine driving a dynamo: the current generated serves to drive a number of electric motors mounted on the axles of the cars. By distributing the driving effort over the number of axles, a rate of acceleration can be obtained which would otherwise be impossible with such a light equipment; since if only one pair of wheels were driven, a much greater weight of the car would be required to secure sufficient tractive effort.



PETROL-ELECTRIC SELF-PROPELLED RAILWAY COACH, NORTH-EASTERN RAILWAY.

Another point in connection with the self-propelled petrol-electric coach deserves attention. The electrification of railways is coming to the front, and electric railways are likely to be more common in the immediate future; consequently the question arises as to how side lines having little traffic are to be economically served; and as it cannot possibly pay to supply, on the third-rail or any such system, current for an intermittent service, how are trains suitable for these side lines to be economically run on the main lines?

The petrol-electric coach appears to solve both these problems. A coach very similar to those built by the North-Eastern Railway Company would be easily equipped with a shoe to pick up current from the third rail, to drive its motors while on the electrified portions of its route; and when it was required to run on to an unelectrified section, the petrol engine could be started without even stopping the coach, and the vehicle could then complete its journey under its own power as an entirely self-contained unit.

Another point in favour of the system is that a coach when put in running order with its tanks full, can stand in its shed, practically indefinitely, without cost, ready to take the road at ten minutes notice, so that it should be useful as a reserve in case of breakdown. Coaches of this description could also be run on ordinary railways in conjunction with "tubes," where it is quite impossible to use steam locomotives on account of the vitiation of the atmosphere. When in the tunnels a coach would pick up the current and not run the petrol engine, but when in the open, on an ordinary unelectrified line, it would run under its own power.

It is probable that, now one railway company has been sufficiently courageous to experiment with what is practically a large motor car on rails, we shall soon see a great development in this direction; and, naturally, once the special requirements are thoroughly appreciated, the equipment will be very much simplified and cheapened.

* TECHNICS, Vol. II., No. 9, Sept., 1904, p. 270.

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The International Bureau of Metric Standards.

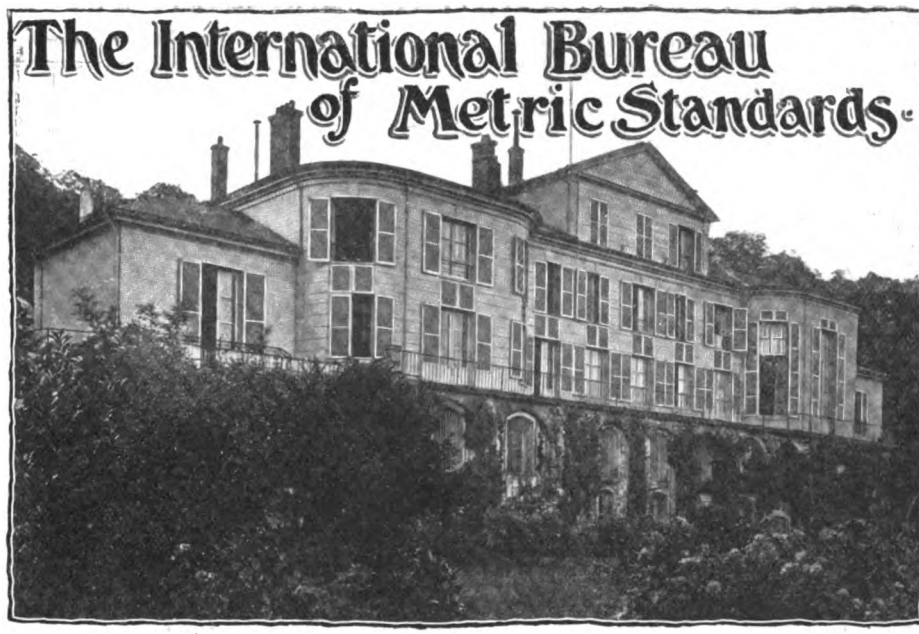

Photo by [*L. Jaumont.*

By JACQUES BOYER.

History and Organisation.

IT is highly probable that ere long the metric system will become universal, since the last of the barriers erected against it by the Anglo-Saxon races seem to be on the point of collapsing. Thus the United States Congress is about to discuss the opportuneness of its adoption by the Administration, and the House of Lords recently passed the second reading of a Bill, introduced by Lord Belhaven, for the purpose of making the metric system compulsory in Great Britain from 5th April, 1906, or a later date to be fixed by the Government. The occasion seems therefore appropriate to describe the International Bureau of Metric Standards, which is maintained by the signatory powers to the "Metric Convention" of 1875, and has done such an amount of important work as to convince even the most biassed of the enormous advantages to be derived from the general adoption of a uniform system of weights and measures.

The International Bureau of Metric Standards is under the management of an International Committee, armed with authority by the General Conference on Weights and Measures, consisting of delegates appointed by the interested Powers. This Conference meets in Paris at least once every six years.

The Metric Convention was originally signed by sixteen nations—Germany, Austria-Hungary, the Argentine Republic, Belgium, Denmark, the United States, France, Italy, Peru, Portugal, Russia, Sweden and Norway, Switzerland, Turkey, and Venezuela—and was subsequently ratified by Servia (1879), Roumania (1882), Great Britain (1884), and Japan (1885). According to the terms of this Convention, the International Bureau of Metric Standards is entrusted with the custody of the international prototypes of the standard meter and kilogram, and is charged with the duty of periodically comparing the fundamental standard of the metric weights and measures employed in different countries for scientific purposes, and with the standardisation of geodetic measuring rods.

To prepare for the performance of this extensive and difficult task, the first thing necessary was the provision and installation of the requisite scientific appliances in a suitable position. The French Government facilitated the accomplishment of this purpose by placing at the disposal of the Committee the Pavillon de Breteuil, illustrated at the head of this article. This is a dependency of the château of Saint-Cloud, in the commune

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of Sèvres (Seine-et-Oise). The situation of the building, surrounded by venerable trees in the bosom of the park, and protected from the disturbing vibrations unavoidably present in towns, fulfils all the requirements of an institution of the kind in question.

The first few years were occupied in repairing the partially ruined edifice, and in constructing a special building—the arrangement of which will be seen in the plan, Fig. 1—destined for purposes of observation. In the present brief notice I cannot hope to describe the minute precautions taken in the fitting up of these metrological laboratories. It must suffice to mention that all the various forms of apparatus are mounted on masonry foundations embedded in the earth, openings being left in the flooring of the rooms for this purpose, so that the operators may carry on their experiments without affecting the instruments.

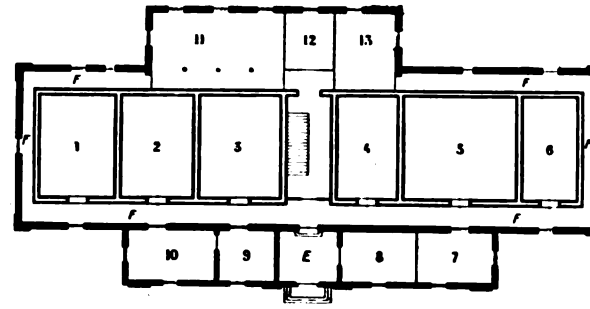

FIG. 1.—PLAN OF THE LABORATORIES.

1, 2, 3, and 4. *Comparing Laboratories.*
5. *Balance Room.* 6. *Michelson Apparatus.*
7 and 8. *Gas Thermometers.* 9 and 10. *Mercury Thermometers.*
11. *Electrical and Optical Apparatus.* 12. *Accumulator Room.*
13. *Chemical Laboratory.* E. *Entrance.* F. *Corridor.*

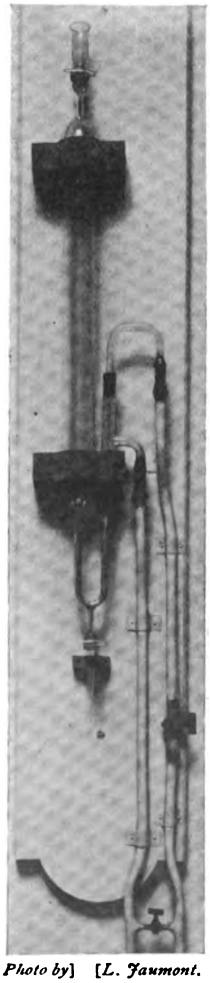

Photo by [*L. Jaumont.*

FIG. 2.
BENOIT'S THERMO-REGULATOR.

To keep the rooms from becoming too cold in winter, the gas supplied to the heating stoves is controlled by a thermo-regulator (Fig. 2) invented by M. René Benoit, the present Director of the Bureau. Part of the gas traverses a small by-pass tap, but the main supply passes through a glass tube, provided with a slot near its lower end, which dips into the mercury seal of a petroleum spirit thermometer. By this means the temperature of the apartment can be regulated to about one-tenth of a degree.

EQUIPMENT.

I shall now shortly describe the chief forms of apparatus used by the physicists of the Pavillon de Breteuil.

For comparing standards of length, which may be defined in metrological science as "standard distances between two marks, or between two parallel surfaces," use is made of comparing machines. Of these, the Sèvres Bureau possesses several types, corresponding to various practical requirements. The essential feature of these instruments consists of two fixed pillars, carrying two microscopes fitted with micrometer adjustments, under which the rods to be compared are brought into position by means of special mechanism.

The comparing machine of Brunner Frères is designed for comparing the equality of *mètres à traits*, that is to say, meter rods, the lengths of which are measured, not between the extremities, but between lines engraved near the two ends. The microscopes of this instrument are rigidly mounted on solid masonry foundations, and are fitted with micrometer scales analogous to those employed in optical instruments. The marks on the bar are sighted, the crosswires of the instruments being adjusted to coincide with them; this process is carried out with respect to both bars to be compared. The head of the micrometer screw is turned through the necessary number of divisions, and the distance corresponding to each division being known, it is easy to deduce the distance separating the two marks. The body of the comparing machine consists of a large structure of cast iron, forming a kind of miniature railway track, on which runs a very heavy carriage supporting a jacketed tank and actuated by a crank and train of gear. In this metallic box are placed the two meter rods to be compared; these can be moved

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longitudinally and transversely by the aid of special mechanism. The operator then brings each rod under the microscope in turn, and compares the lengths of the two by reading off the position of the marks at the end of each.

The comparing machine represented in Fig. 3 is designed for standardising geodetic measuring rods, which at the present time are made in lengths of four meters, in order to reduce the number of measurements without unduly increasing the weight of the rods. To enable the length of these rods to be compared with a metric standard, and also

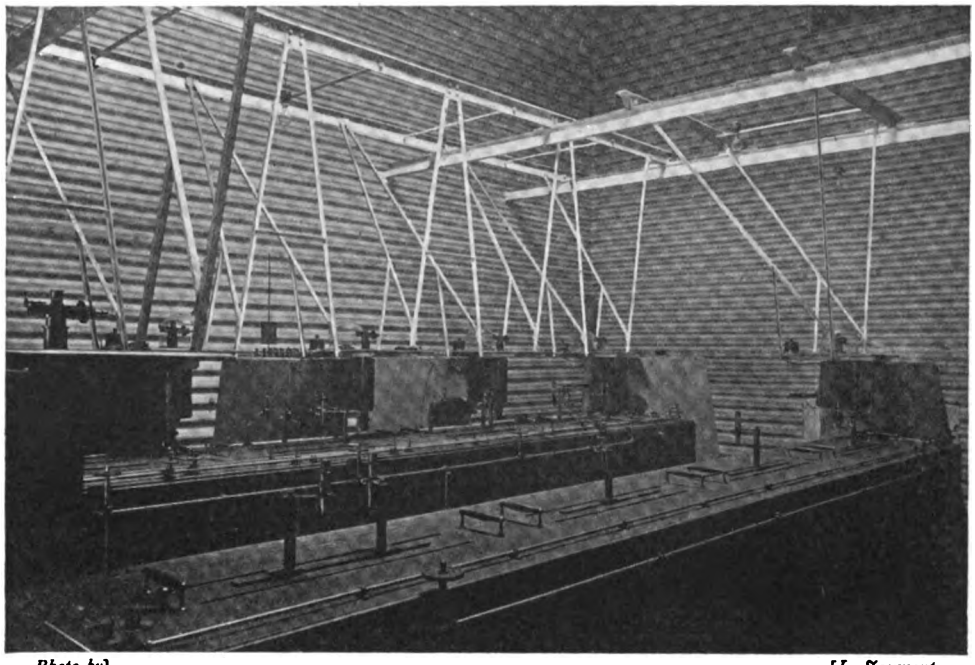

Photo by] [*L. Jaumont.*

FIG. 3.—COMPARATORS FOR GEODETIC STANDARDS.

to determine their degree of expansion between the extreme limits of temperature to which they are liable to be exposed, the geodetic comparing machine comprises five microscopes in exact alignment, mounted on stone pillars, which in turn rest on a solid masonry foundation. The whole constitutes, in fact, four comparing machines (each of one meter range), placed one beyond another. Two other microscopes are arranged in a straight line parallel to the first. A frame, mounted on rollers, runs on rails embedded in the foundation, and carries two large troughs, one of which contains two benches, the other a single bench which can be adjusted along a micrometer scale. The movement of the frame and troughs is determined by a worm, actuated by a motor. By this means, the first trough can be brought into position under the row of microscopes, and then under the two single instruments. The rod under examination is standardised by the aid of the row of five microscopes, with which object it is placed on one of the benches, while the standard meter rod is placed on the other. The relative agreement of the marks on the standard rod and those bounding the first meter on the geodetic rod is then determined by the two first microscopes; which done, the standard rod is placed opposite the second portion of the other, and so on in succession.

The longitudinal-displacement comparing machine (Fig. 4) was recently constructed by Messrs. Barriquand and Marre, of Paris, to the designs of Messrs. Benoit and Guillaume, for the purpose of comparing short lengths and determining the errors in the graduation of a standard. It consists of a strong cast-iron tank, resting on three levelling screws, and containing a double longitudinal slide on which moves a bench, worked by a rack actuated by a graduated wheel. On this bench are mounted others, the height of which can be regulated as required, and on these latter are placed the standards

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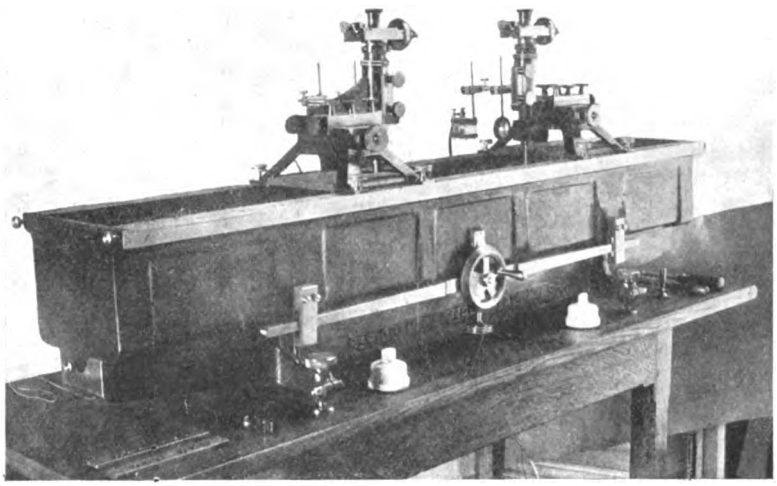

Photo by] [*L. Jaumont.*

FIG. 4.—APPARATUS FOR MEASURING LONGITUDINAL DISPLACEMENTS (BARRIQUAND AND MARRE).

under examination. The cover of the tank is properly levelled, and on it are fixed, by means of screws, the stands of two microscopes, which can be set as close as one centimeter apart. The driving wheel is worked by hand, or by a lever keyed on to its shaft. The wheel is graduated merely for the purpose of indicating differences of a fraction of a millimeter, to prevent errors in reading the marks.

The universal comparing machine (Fig. 5) of the International Bureau was made by Messrs. Starke and Kammerer, of Vienna, to whom it does great credit. By reason of the two movements (longitudinal and transverse) of this instrument, and the mobility of the microscopes with which it is fitted, it may be used for many different verifications. The instrument comprises a double iron beam, A, mounted on two pillars and supporting two microscopes, which can be set as far as two meters apart: also a heavy carriage, B, running on rails and surmounted by three pairs of hollow columns, C, with vertically adjustable cores supporting two benches, D, and a graduated scale, E, two meters in length. Convenient to the operator's hand are the cranks governing the cross motion of the carriage and setting the benches to coincide with the scale. The whole arrangement is enclosed in a mahogany case (not shown in Fig. 5), which is fitted, in the upper part of the front, with two windows for illuminating the microscopes and reading the

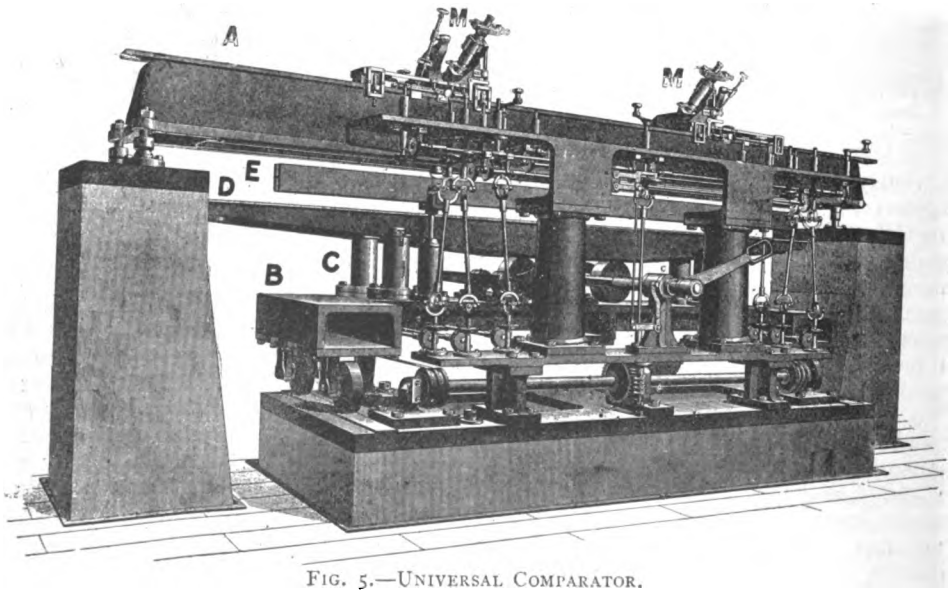

FIG. 5.—UNIVERSAL COMPARATOR.

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thermometers. The cross motion of the carriage is effected by steel bands actuated simultaneously by the mechanism; the other movements are transmitted by rods. For the longitudinal motion, one of the benches supports a carriage worked by a rack and pinion, and connected with a vertical rod by a universal joint.

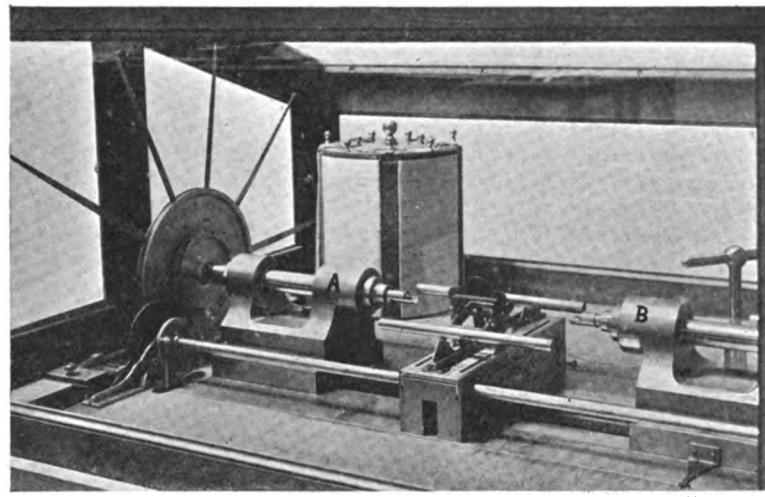

Photo by] [*L. Jaumont.*

FIG. 6.—AUTOMATIC COMPARATOR (COMMANDANT HARTMANN).

Commandant Hartmann's automatic comparing machine (Fig. 6), which was primarily designed for the verification of gauges used in the manufacture of arms, is employed in metrological measurements when it is desired to examine a standard rod, bounded by two parallel surfaces, by the direct contact method. The instrument consists of a solid bench of steel, on which are mounted two poppets, one of them, A, being fixed, whilst the other, B, can be moved by a screw. The standards to be compared are placed on a carriage, situated between the two poppets, and are brought successively between the poppet cones by the automatic travel of the machine. The nut of the block, A, is traversed by a screw, terminated by a double-groove pulley, which is fitted with ten flexible rods, each carrying a stylus at its

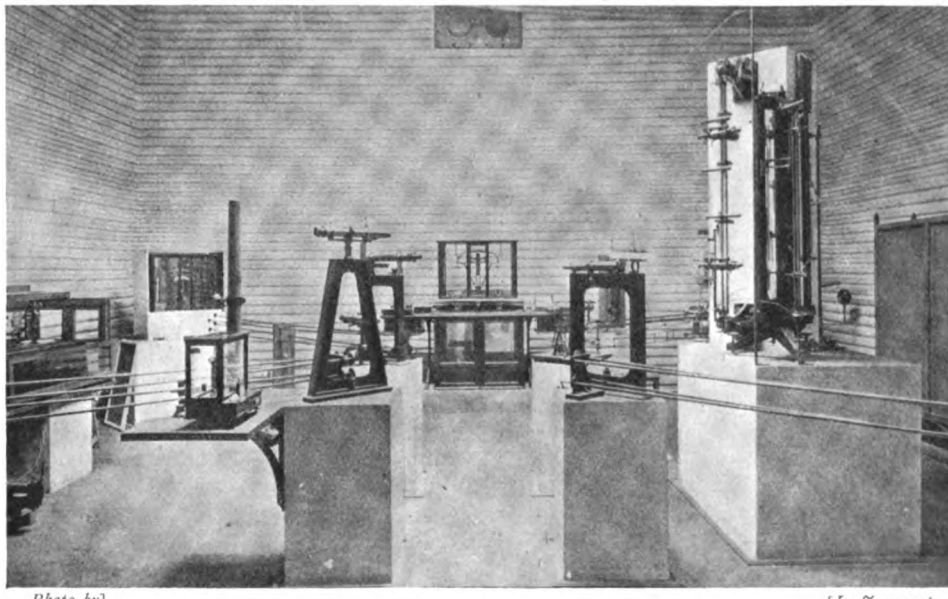

Photo by] [*L. Jaumont.*

FIG. 7.—BALANCE ROOM.

(*The long rods, seen to the right and left of the illustration, serve to operate the balance from a distance of four meters.*)

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end. A recording cylinder is placed in the path described by the stylus during the rotation of the pulley.

The standards having been placed in position, the comparing machine is set in motion by the aid of an electric motor. This causes the pulley to rotate, and actuate a belt, which in turn moves a flat-ended steel rod and brings the same into contact with the standard. At this instant the pulley stops, and a lever arm, pressing on one of the rods, forces the terminal point into the paper on the recording cylinder. By means of an ingenious device, the screw is then returned to its original position, the carrier removes the standard from between the poppets and puts the other standard in its place. The cycle of operations recommences, and a second hole is pierced in the paper on the recording cylinder, which has moved onward a little during the interval. By repeating the operation with the two rods alternately, several times in succession, two rows of perforations are obtained on the recording cylinder, and the distance between these rows represents the difference in the lengths of the rods. The pitch of the screw being one millimeter, and the length of stroke two meters, the true difference in the length of the rods under examination is found by dividing the mean result by 2,000.

The second class of instruments used at the International Bureau of Metric Standards comprises those employed for verifying standards of mass. The balances serve more particularly for verifying standard kilograms, and nearly all these instruments are constructed in such a manner as to be operated from a distance.

The method of procedure is as follows: On the evening before the test is to be performed, the operator places the weights he will require next day inside the case of the balance; after this he does not approach the instrument again, for fear of the balance being affected by the heat of his body. Twenty-four hours afterwards, by means of the long levers shown in Fig. 7, which rest on blocks of masonry, he performs the weighing from a distance of about 13 ft. (four meters), the ingenious mechanism connected with the balance enabling the weights to be placed on the pans, the latter released from their supports, and so on. The oscillations of the pointer are examined through a telescope supported by a metal holder mounted on the pillars carrying the lifting mechanism. The graduated scale on the balance is reflected in a mirror attached to the pointer, and the movements of the image of this scale are observed through the telescope, as the balance swings to and fro. All that the operator has to do is to note three successive extreme positions of the swinging pointer, when the position of equilibrium can be deduced by a simple calculation.

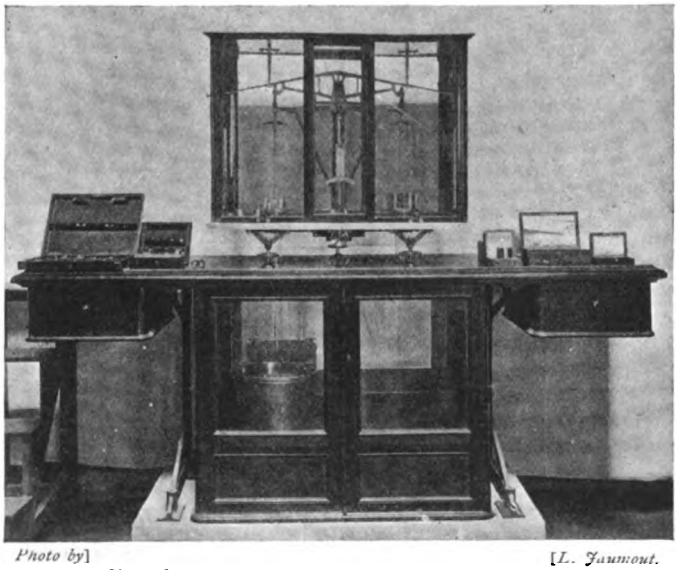

Photo by [*L. Jaumont.*

FIG. 8.—HYDROSTATIC BALANCE (RUEPRECHT).

There is no need to dwell on the arrangements devised by the various makers—Rueprecht, Arzberger of Vienna, and Bunge of Hamburg—thanks to which the physicists of the International Bureau are enabled to detect a difference of nearly one-hundredth part of a milligram in the weight of two kilograms. Nevertheless, brief mention should be made of the large hydrostatic balance (Fig. 8). The vessel serving for the hydrostatic determination of the cylinders can be seen in the lower case. This receptacle is fitted with a screw, by means of which the two stays supporting the cylinders can be moved simultaneously by the aid of elastic girths. The tare, consisting of nickel weights,

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can be seen in position on the right-hand pan, whilst platinum-iridium weights on the opposite pan serve to establish the equilibrium of the balance. The instrument will weigh up to five kilograms.

The third class of apparatus employed is used for *thermometric investigations*. The instruments include *mercury*, *gas*, and *toluene thermometers* of the greatest precision, as well as pressure gauges and barometers constructed with the greatest care for the measurement of pressures.

A few words may be devoted to the large barometer and the standard pressure gauge (Fig. 9), which form typical examples of instruments of high precision. The barometer, AB, mounted in a case, is connected at the lower end with a steel vessel, by means of which it communicates with a lateral reservoir containing mercury. The lower tube is provided with a straight pointer which is vertically adjusted by a micrometer movement. The pointer and its image can be read by the aid of a cathetometer, C. On the same base-plate is placed a pressure gauge, M, one of the branches of which contains six pointers, arranged along the axis and situated at intervals of 16 centimeters. D and E represent the reservoirs for adjusting the height of the mercury in the barometer and pressure gauge. For atmospheric pressure determinations the lateral reservoir is first lowered and then raised, so as to bring the upper meniscus within a very short distance of the corresponding pointer. Then the lower pointer is moved downward, and finally readings are taken with the two telescopes. By this means the errors of observation are reduced to nearly the one-hundredth part of a millimeter.

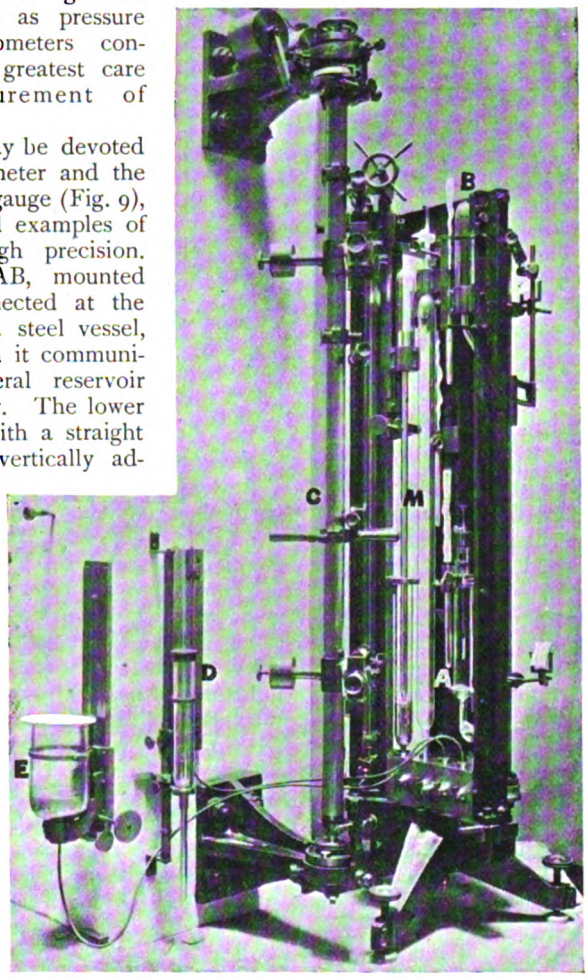

Photo by [*L. Jaumont.*

FIG. 9.—STANDARD BAROMETER.

METROLOGICAL WORK DONE.

Having passed in review the instruments used at the International Bureau, we come to the final section of this article—the history of the work done since the institution was founded, chiefly devoted to the preparation of the new international standards of the *meter* and the *kilogram*.

In accordance with the decision of the International Commission which met in Paris in 1872, a replica had to be made of the meter constructed in 1799 and stored in the Archives of France. Instead, however, of preserving the original form of a flat bar with rounded ends, it was considered preferable to have strong standards, marked on the plane of the neutral fibres, so that the length is independent of the mode of suspension. Moreover, the material selected consisted of an alloy composed of 90 per cent. of platinum and 10 per cent. of iridium. Finally, on account of the expense of these metals, an economy was effected by making the rods of an X cross section (Fig. 10), thus obtaining a maximum of rigidity with a minimum of weight.

To prepare the international meter, it was necessary to proceed in the following manner. In the first place, a provisional standard was constructed, approaching as nearly as possible

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to the length of the one in the Archives. By repeated verifications the new standard was found to measure only six microns (six one-thousandths of a millimeter) more than the original. The length of the provisional standard having been determined, other prototypes, to the number of forty, were constructed by its assistance, and the verification of these showed that each of them differed from the original standard (that in the Archives) by not more than three microns. The one nearest in length to the original was selected as the International Standard, and has ever since been indicated in all diplomatic and scientific documents by the symbol M. Finally, this rod was compared anew with all the others. The calculations were performed for the most part by M. René Benoit, and these metric prototypes received the sanction of the General Conference of 1889.

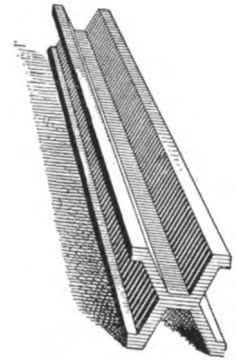

FIG. 10.—FORM OF NEW STANDARD METER.

The *international meter* was enclosed in a safe, and stored in a deep vault fastened with three locks, the keys of which are held by the Director of the Bureau, the President of the International Committee, and the Director-General of the Archives of France, respectively. Lots were afterwards drawn for distributing among the signatory Powers the forty prototypes which, having been standardised on the meter, will ere long determine the future unit of length throughout the world.

The various operations being concluded, and the bars cleaned with hydrochloric acid, they were enclosed in cases designed by Dr. O. J. Broch, no pains being spared to ensure their safe arrival at their destinations. The cases (Fig. 11) were made of two semi-cylindrical pieces of beech, fitting one into the other and provided with velvet-lined grooves for the reception of the bar. The whole was enclosed in a strong brass tube, closed at one end and fitted with a locking screw cap at the other. Thus packed, each of the standards was forwarded to its final destination, whether Russia, Japan, the United States, Venezuela, or elsewhere.

A similar task was performed in connection with the standard kilogram, and the International Committee selected, from the three specimens obtained, the one most nearly approximating to the kilogram in the Archives of France, this specimen being designated by the symbol K. This, the *international kilogram*, was removed to Sèvres, where its volume was determined by the aid of the Rueprecht hydrostatic balance; subsequently forty copies, destined to serve as national prototypes, were made. The physicists of the Pavillon de Breteuil subsequently carried out the repeated determinations entailed by the examination of these standards and their verification with the international kilogram; and the Assistant Director, M. Ch. Ed. Guillaume, is still engaged in perfecting the methods relating to this important subject.

Among the other noteworthy researches pursued at the International Bureau during the first twenty-five years of its existence, mention may be made of those instigated by Michelson. By means of a series of ingenious processes which are beyond the scope of the present article, this American scientist has succeeded in comparing the fundamental base of the metric system with the wave-length of the red cadmium line. In the words of its discoverer, this unit seems to be one of the most constant dimensions in nature. It may, therefore, be claimed that, even if all the existing standards were destroyed in a cataclysm, we should be able, by reversing the method adopted by Michelson, to reconstruct all the standard metric units from the data furnished by him. Truly, the promoters of the meter were not deceived as to its future when they endowed it with the proud device: "For all ages and all peoples."

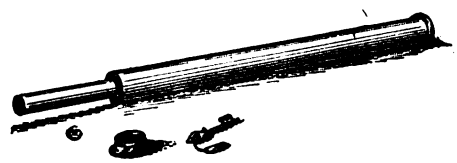

FIG. 11.—CASE FOR PROTOTYPES OF STANDARD METER.

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ARRANGEMENT OF MACHINERY IN A MODERN COTTON MILL.

PART IV.—THE MILL PLAN.

By WM. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

IN setting to work on the plans shown in the last issue (the November number), which are reproduced in the current number (Figs. 4 and 5), we commence with the total number of spindles as a basis. Sometimes the amount of yarn is used as a basis, but since one is easily calculated from the other, it little matters which is used.

In the present instance we are going to spin 32s twist and 45s weft, and the mill is to contain about 80,000 spindles. The number of weft spindles and twist spindles are not stated, so this must be given as a condition decided upon by the spinner to suit the conditions of his market. The illustrations are drawn on the assumption that 36,064 spindles will be used for spinning weft yarn and 42,320 spindles for spinning twist yarn. Knowing the number of spindles and the counts of yarn to be spun, we can easily find the total production of the mill and the amount of raw cotton required for spinning into that yarn.

One spindle, spinning 32s twist, will produce 30 hanks per week, so that 42,320 spindles will spin—

$$\frac{\text{Spindles.}\ 42{,}320 \times 30\ \text{Hanks.}}{\text{Counts.}\ 32} = 39{,}675 \text{ lbs. of yarn per week.}$$

In the same way, if one spindle spinning 45s weft produces 27 hanks per spindle per week, then 36,064 spindles will produce—

$$\frac{\text{Spindles.}\ 36{,}064 \times 27\ \text{Hanks.}}{\text{Counts.}\ 45} = 21{,}638 \text{ lbs. per week.}$$

The total production of the mill will be 61,313 lbs. of yarn per week.

We must now find the amount of raw cotton required to produce 61,313 lbs. of yarn. To do this we must take into account the incurred waste as the cotton passes through the various processes. This loss varies in different mills, but, as an average, 14 per cent. may be taken as the waste between the first and last process.

This 14 per cent. loss will equal

$$\frac{14 \times 61{,}313}{100} = 8{,}583 \text{ lbs. per week,}$$

so that the raw cotton will be

$$\text{Yarn.}\ 61{,}313 + \text{Waste.}\ 8{,}583 = 69{,}896 \text{ lbs. per week.}$$

In other words, 69,896 lbs. of cotton must be fed into the bale-breakers in order to produce 61,313 lbs. of finished yarn.

The loss in passing through the scutcher-room will amount to about 3½ per cent., so that the scutchers must make 67,450 lbs. of laps ready for the cards.

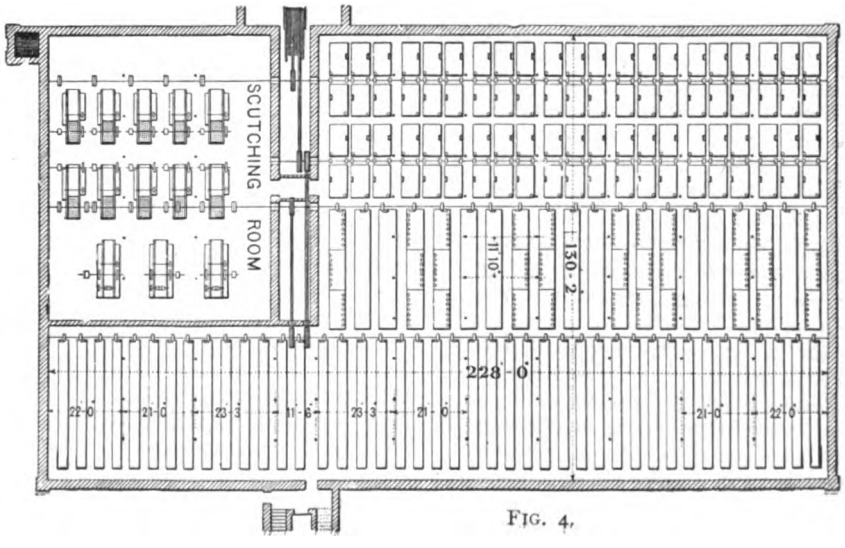

FIG. 4.

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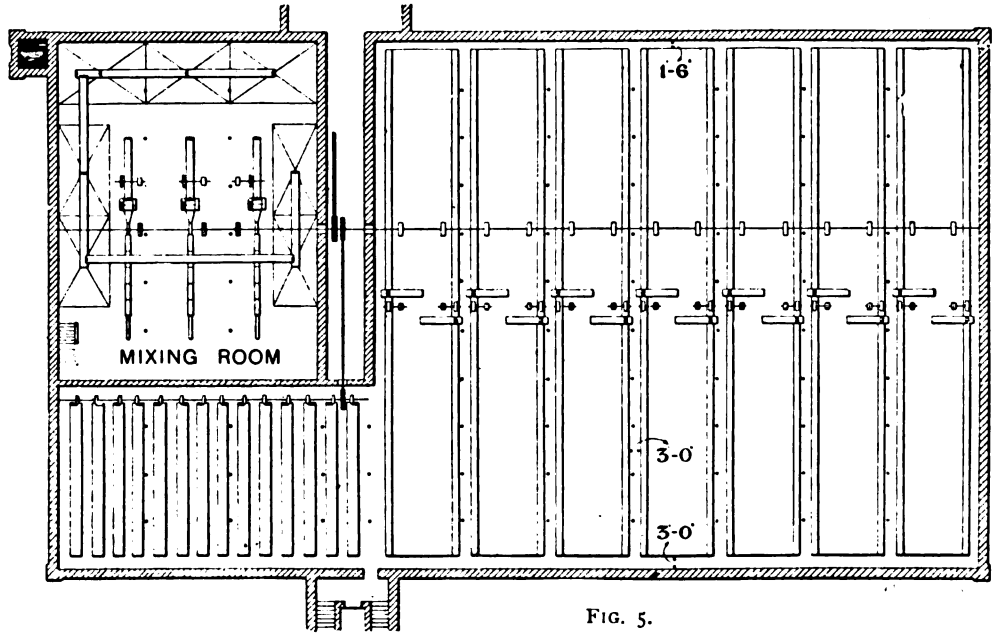

FIG. 5.

An opener produces up to 30,000 lbs. per week, so this will necessitate three openers.

A scutcher will produce from 12,000 to 20,000 lbs. per week, so that four finishing scutchers are required, as well as four intermediate scutchers, thus giving us eight scutchers. Each opener (horizontal exhaust opener) will have its hopper feeder supplied with cotton by a porcupine opener from the mixing room above, direct from the mixing stacks. These are shown in Fig. 5, and a comparison of Figs. 4 and 5 will show how the tubes from the porcupine openers come over the entrances to the exhaust openers. In planning the card room a good deal of judgment must be exercised in deciding upon the details of each set of machines, so far as our plan is concerned. The question of twist and weft will not necessitate the preparing machinery being divided up into sets for each purpose, though a manager will afterwards probably do so. We have to deal with averages, and strike a suitable average roving, etc., to suit a general arrangement.

For the purpose of our plan a card may be taken as producing 766 lbs. per week; to get this we make a sliver of 0·154 hank and run the doffer at fourteen and a half revolutions per minute. Our plan is based on these conditions; but the student will readily understand that there is no mathematical reason for this: no theorising will indicate that these are the only factors, or that the given production of the card is the only one that will suit the mill we are planning. It is all a question of practical experience, and different managers have varying ideas upon the subject; some will run their cards to the full extent, whilst others will go in for slower speeds and lighter productions; but in any case, subsequent processes must be worked to suit the conditions fixed, and machinery of sufficient number arranged to deal with them.

In the card room there will be a loss of five per cent. in waste, so that the total production of the cards will be—

$$\frac{105 \times 6,1313}{100} = 64,378 \text{ lbs. of card sliver.}$$

Each card produces 766 lbs. per week, so that we obtain—

$$\frac{64,378}{766} = 84 \text{ cards.}$$

It will be as well at this point to see what productions we allow for in the draw frames and fly frames. The cards deliver 64,378 lbs. per week and the mules deliver 61,313 lbs. per week. There will be waste between each set of the intermediate processes, so if we desire to be fairly exact the losses must be taken into account. A table such as the following will show at a glance the productions:—

	lbs.	lbs. waste.
The cards produce . .	64,378	
The draw frames produce .	63,918 =	460
The slubbers produce . .	63,458 =	460
The intermediates produce	62,998 =	460
The roving frames produce	62,538 =	460
The mules produce . .	61,313 =	1,225

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The above table has been made by simply dividing the waste between the cards and the mules into four equal parts, and reducing the production at each process by the amount. This is the easiest method, and gives practically the same results as if percentages were used, besides saving the extra trouble involved in calculating small percentages and then reducing.

The draw frames will have six ends up, having the same sliver as the card, *viz.*, 0·154 hank. A diameter of an inch and a quarter for front roller has been used, running at 360 revolutions per minute, so that we get a production of 830 lbs. per week. This 830 lbs. divided into 63,918 lbs. gives us 77 finishing deliveries. A drawing frame of three heads each with seven deliveries is usual, so $77 \div 7 = 11$ draw frames of three heads. The slubbing frame will have a 0·7 hank, and its production is 50 hanks per week per spindle, so that, as the total production of the slubbers is 63,458 lbs. per week, we must have

$$\frac{63{,}458 \times \cdot 7}{50} = 888 \text{ spindles.}$$

The intermediate frame will deliver a 1·7 hank roving, so that its production per spindle will be 51 hanks per week. The total production of the intermediate frames is 62,998 lbs. per week, so that we obtain :—

$$\frac{62{,}998 \times 1 \cdot 7}{51} = 2{,}099 \text{ spindles.}$$

The roving frame will produce 41 hanks per spindle per week, and make a four and a half hank roving. As the total production of the roving frames is 62,538 lbs. per week, we obtain :—

$$\frac{62{,}538 \times 4\frac{1}{2}}{41} = 6{,}854 \text{ spindles.}$$

We already know the number of spindles that are to be used in the weft and twist mules for the production of 61,313 lbs. of yarn, so it remains now to find the dimensions of the various machines, and plan them to the best advantage.

It will now be well to tabulate the results already found, and put in the particulars of space of spindles, width, etc., so that a glance at the table may suggest certain directions in which we may make trial arrangements. Practically no plan is ever made at the first attempt: many schemes are tried, and a number of re-arrangements drawn out before even the most suitable general arrangement is found. When this is done, the final scheme, from different draughtsmen, will show wide variations in the arrangement, even when the actual machines are the same in number and dimensions. Having a typical mill plan before us, we can only indicate the method adopted in designing it.

Machine.	Length.	Width.	Space.
	ft. in.	ft. in.	in.
Opener and Hopper Feeder .	25 2	6 7	—
Scutcher	16 6	6 7	—
Card	10 0	5 2	—
Draw Frame, 3 heads, 7 dels., 16 in. roller	35 4	5 0	—
Slubber	—	5 0	8
Intermediate Frame . . .	—	3 0	$6\frac{1}{2}$
Roving Frame	—	3 0	5
Pair of Mules (twist) . . .	—	20 0	$1\frac{3}{8}$
Pair of Mules (weft) . . .	—	20 0	$1\frac{1}{8}$

NOTE :—The width of a pair of mules 64 inches stretch is only 18 feet from back of creel to back of creel.

The next points to consider are the lengths of the various machines. It is on these lengths that the width of the mill will depend if we are allowed a free hand in designing the mill; but if the width of the mill is already fixed for us by the space at our disposal, the length of the roving frames and mules will be limited to that extent.

In the present case we can fix the width ourselves; this gives us freedom to decide on the position of the pillars and their spaces.

It is a general practice now to space the pillars lengthwise in the mill, so as to have them only along the alley at the back of the mules; this means a long span, usually of 21 feet, leaving sufficient space for passing along the back of the mules to fill the creels.

A glance at the table of dimensions just given will show that this span between the pillars permits four flyer frames, with suitable spaces between them, to be arranged. Three cards can also be set in the same span, as well as permitting a convenient arrangement of slubbers and draw frames.

The space of pillars in the width of the mill is generally 11 to 12 feet, though this is not essential. It is well to make a trial by arranging a rough plan of a few machines in the preparing room. We see that eighty-four cards will make four rows, each row with twenty-one machines, or three rows with twenty-eight cards in each row. If the latter arrangement is tried, and a calculation made as to the total length required by fifty-six intermediates and rovers, we shall find that the blowing and mixing rooms will be awkward to arrange, if space is to be saved. Rough draft of the four rows of cards will show a neat arrangement, and as the length

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of the card is 10 feet over all, we can, as a preliminary, settle on the space of the pillars as 12 feet, thus allowing for a two-feet space between each two rows.

The draw frames (three heads of seven deliveries) occupy 35 feet 4 inches, and these take up another three spaces of pillars. Following on with the fly frames, we shall find that the total width will depend on their length. These machines are made as long as possible in modern mills, but there is no rule in the matter; some idea of length must already exist, but this length may, for the present, be taken as about 40 feet. Allowing for spaces between the ends of the machines, this will take up another four spaces of pillars. We now have, in the rough, a width of 11 × 12 feet = 132 feet for the inside of the mill. If we now commence to design the blowing room and fix the engine house, we shall be in a position to settle the plan of the spinning rooms.

A drawing is given in Fig. 6 of the scutching room. The pillars, already roughly sketched, allow for a neat arrangement of the three openers and ten scutchers. In settling this we must see that space is left for good passages between the machines and also room for storing laps. As the scutching room is the room in a mill where a fire is most likely to occur, it is isolated as far as possible from the rest, and a fireproof passage made from it to the card room. The driving ropes usually pass through the space thus left: this fixes the position of the engine house. Our rough draft plan will at once suggest that the width of the blowing room will be equal to the space covered by the four rows of cards and the length of the draw frames. It will be noted that the length of the mill has been increased by the blowing room and rope race, giving us a greater length on the ground floor for the intermediates and rovers. Calculation will, however, soon show us that this length will not accommodate the whole of them; but a little consideration will indicate that as the mixing room will be on the floor above, there will be a space left that cannot be used for mules. On trying a roving in the space, we shall find it fits conveniently and, moreover, allows for fourteen of these machines. The space occupied, in

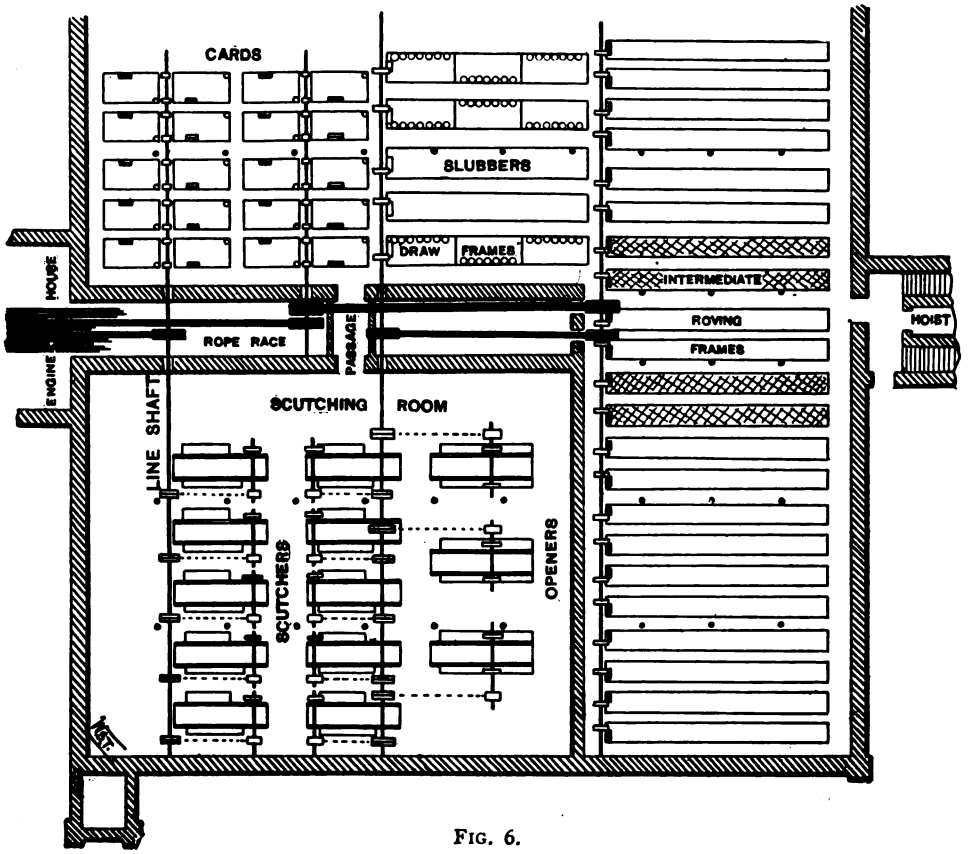

FIG. 6.

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the rough plan, by four rows of cards, the blowing room and the rope race will accommodate forty-two intermediate and roving frames, thus leaving roving frames for the room above.

It will now be seen that we have a good idea of the rooms to be occupied by the mules. A glance at the plan will show us that the first room can contain seven pairs of mules and the second room also seven pairs of mules. The rope race, going up through the mill, is of course lost space so far as machines are concerned, so it is not taken into account. At a low estimate there must be between 50 and 60 mules in the mill, so this decides the question of the number of spinning rooms, *viz.*, four.

In the first mule room we place the weft spindles, $1\frac{1}{8}$ inch space. A passage of three feet must be allowed at one end, whilst at the other end half this space of passage is sufficient. The rough draft of card room gave us about 132 feet as the width of the mill, so subtracting 4 ft. 6 ins. (passages) from 132 ft., we have 127 ft. 6 ins. for length of mule.

Now in settling the length of the mule (or, what is the same thing, the number of spindles), we must first have an even number of spindles, and also arrange to suit the rollers, and the number of ends going through, the mule can only be shortened or lengthened by this multiple. In this case the most convenient number of spindles comes out as 1,284 for the mule. Having this number, we can now commence our real plan and work backwards.

First we calculate or take from a table the length of a mule of 1,284 spindles of $1\frac{1}{8}$ inch space; this equals

$1{,}284 \times 1\frac{1}{8} + 6$ ft. 3 ins. $= 126$ ft. $10\frac{1}{2}$ ins.

This added to the passages, 4 ft. 6 ins., gives a width of room equal to 131 ft. $4\frac{1}{2}$ ins. For the sake of avoiding fractions of an inch in the space of the pillars, we make the width of the mill on the ground floor 132 feet from wall to wall; dividing this by the number of spaces (eleven) we found suitable in the rough draft, we get 11 ft. 10 ins. as the distance between the centres of the pillars. With this settled, it becomes an easy matter to arrange the machines in their definite positions.

An enlarged drawing of the position of the ground floor is given in Fig. 6. It will be noted that the pillars, owing to their spacing, supply us a ready means of arranging the various machines. The scutching room allows two lines of scutchers between the pillars. The machines are so placed that the laps from the openers can be taken from them, and, with the least possible labour in carrying, placed on the lattice of the first scutcher, and from there on to the finishing scutchers. The cards lend themselves to an easy arrangement, the driving shaft being placed between two rows. The student will note that the space between each card at the side is sufficient for a person to pass, but is not wide enough to allow any carrying of laps, cans, etc. A good passage for this purpose is therefore allowed after every third card. The spacing of the pillars in some mills will not permit of a good wide passage between the cards as shown in the plan, and in such cases the wide passage is made at longer intervals. In any case a wide passage must be arranged at suitable intervals, in order that laps, cans, and workpeople can pass to and fro without inconvenience or danger.

Owing to the isolated condition of the blowing room, some laps have to be carried the whole length of the card room. This means good passages between the ends of the cards. Sometimes the laps are carried by means of a rail overhead, resting on a carrier suspended from it; in other cases a railway on the floor is installed; both methods save time and labour in passing the laps forward. In arranging the draw frames we must divide them up among the cards so that each will deal with its proportion of card cans. The slubbers are set between the draw frames, so that the cans are taken to the back of slubbers with a minimum of carrying. On account of there being eleven draw frames and only nine slubbers, we are compelled to introduce a little irregularity in the position of the machines. The slubbers are placed front to front, and a draw frame is set facing the back of each slubber, so that the cans have simply to be lifted across the passage between the two machines. Fig. 4 will show how the extra draw frames have been arranged.

The length of the slubbers is made almost equal to the length of the draw frames, this giving a very uniform disposition to the whole line. Each slubber has ninety-eight spindles, 8 inches space, so that the length will be 35 feet 8 inches, or only 4 inches longer than the draw frames. It will be noted that the outline of one of the slubbers encloses some of the pillars; this simply indicates that the pillars are at the back of the machine and among the cans. The overall dimensions of the machines must always include everything that forms part of the machine when it is in full working order.

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In regard to the intermediates and rovers, these are made as equal in length as possible and arranged so that the bobbins from one can be carried with the least labour to the creels of the other. Our plan is not ideal in this respect, owing to the fourteen roving frames in the first spinning room, but this is the result of choosing the lesser of two evils. Otherwise we get a convenient arrangement, and the intermediates can be readily distributed among the rovers in the card room. The machines are in pairs, and spindles face spindles, care being taken that the pillars are placed at the back of the frames.

Each intermediate has 132 spindles, $6\frac{1}{2}$ inches space, giving a length of 38 feet 9 inches. The roving frames have 172 spindles, 5 inches space, with a length of 38 feet 10 inches.

In planning the second, third, and fourth spinning rooms, it must be remembered that the walls of the mill become thinner; this enables a few extra spindles to be put into each mule in each higher room. The room over the mixing room in the second spinning room is used as a store room for cotton, and has the bale breaker placed in it.

The arrangement of the mixing room is a simple matter. The sides of the room are divided according to the number of mixings required, and lattices arranged to distribute the cotton from the bale breaker in the room above. By means of clutches the several sections of the lattices in the mixing room can be arranged to drop the cotton on to the mixing desired.

The three porcupine openers in the mixing room are coupled up by tubes with the exhaust openers in the blowing room, and regulated by these latter machines. The third and fourth spinning rooms extend the full length of the mill, so that ten pairs of mules can be placed in each.

The driving of the mill is the next consideration. The two line shafts for the cards can be driven from the engine direct, and one of them extended into the scutching room. The fireproof passage limits any further direct driving from the engine on the ground floor, so the second card line shaft is used to drive the line shaft for the intermediates and rovers. Owing to the slubbers being so near to the cards, their line shaft is driven by driving back from the flyer frame shaft. The line shaft for slubbers and draw frames, if extended, serves to drive the counter shafts for both the intermediate scutchers and openers, the details of which are shown in Fig. 6.

The mules in each room are driven through a main line shaft from the engine. In the second room this shaft drives the roving frames and machines in mixing room, as shown in Fig. 5.

In regard to the power required this must be left over for the present, but two words of advice may be given, *viz.*: Allow a good margin in the power for the mules, so that if a number of mules happen to start out from the roller beam at the same moment, there will be sufficient reserve of engine power. Also allow for at least thirty per cent. for engine and driving shafting, and machines running on loose pulleys.

THEORY OF STRUCTURAL DESIGN.

Part XII.—Brackets on Pillars.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

THE brackets which occur on the sides of steel stanchions occasionally project to such an extent that the stresses produced by bending are far in excess of the pure direct compression, so that beam formulæ become necessary, and the usual pillar formulæ become valueless for the case in hand.

Merely as a simple illustration of an important principle, let us take the case of the pillar shown in Fig. 48, where the forces and reactions are shown by arrows. The horizontal arrow B, at the top of the pillar, represents the force which is necessary to prevent the pillar from toppling over.

The horizontal arrow B_1 at the foot of the pillar represents the reaction which is necessary to prevent the foot of the pillar from sliding towards the reader's left hand. In practice, the upper horizontal force would be provided by some girder or other tie; and the lower horizontal force would be provided by the resistance to shearing of the bolts which would be used to fix the pillar down to the foundations. The external forces acting on the pillar are A, A_1; B, B_1.

The couple produced by the application of the load A, and the upward reaction A_1 = 20 lbs. × 4 feet = 80 pound-feet.

To maintain equilibrium, the opposing

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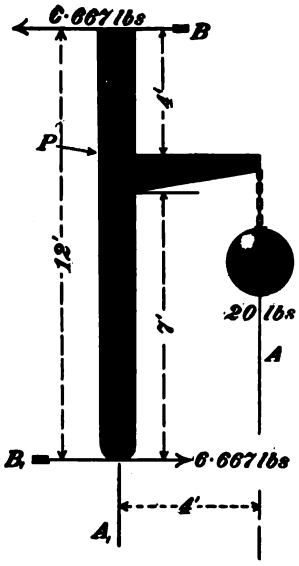

FIG. 48.

couple B, B_1 must have an equal moment. Thus, B lbs. × 12 feet = 80 lb.-feet; ∴ B = 80/12 = 6·667 lbs.

With these forces acting, it can be shown that the two conditions for equilibrium are fulfilled.

1. The vector sum of all the external forces is zero; *i.e.*, the force polygon is closed, or in other words, there is no unbalanced tendency to change of position; because the upward and downward, leftward and rightward forces nullify each other.

2. The algebraic sum of the moments of all the external forces acting round any point whatsoever is zero; *i.e.*, there is no unbalanced tendency to rotation.

The bending moment across a horizontal section at P = (6·667 × 4) pound-feet.

The bending moment across a horizontal section at a point 7 feet above the base = 6·667 lbs. × 7 feet.

In Fig. 49, the projecting bar has been replaced by a framed bracket such as might be employed for carrying a gallery, and a central load of one ton has also been placed on the top of the pillar. Since the algebraic sum of the moments of the forces round *any* point must be zero, we may take the point D for a start.

D is convenient because it forms the intersection of the lines of action of three of the forces.

The leverage arm of these three forces of 4 tons, 1 ton, and ¾ ton respectively is zero, and, therefore, they drop out of our equations, and we are left with 16 feet × F tons = 3 tons × 4 feet. Dividing both sides by 16 we get F = ¾ ton.

We know that this is also the amount of the horizontal force at the foot of the pillar. If this does not appear perfectly obvious, let the reader take moments round a point at the top of the pillar and find the amount of the horizontal force at the base.

Fig. 50 is the triangle of forces for the joint at B in Fig. 49. By application of Euclid, Book I., Prop. 47, it is clear that the force in B C = $\sqrt{18}$ = 4·242 tons.

This result could easily have been obtained with sufficient accuracy, for purposes of practical design, by simply scaling the diagram; but it is my present purpose to prove by trial that the sum of the moments round any point is zero, therefore greater accuracy is necessary.

Take moments round E; and let clockwise moments be positive, then—

$$(3 \times 4) - (\tfrac{3}{4} \times 4) - (\tfrac{3}{4} \times 12) = 0.$$

Instead of taking the vertical force of 3 tons, we may take its diagonal component in the direction B C of Fig. 49, and its horizontal component in the direction E B.

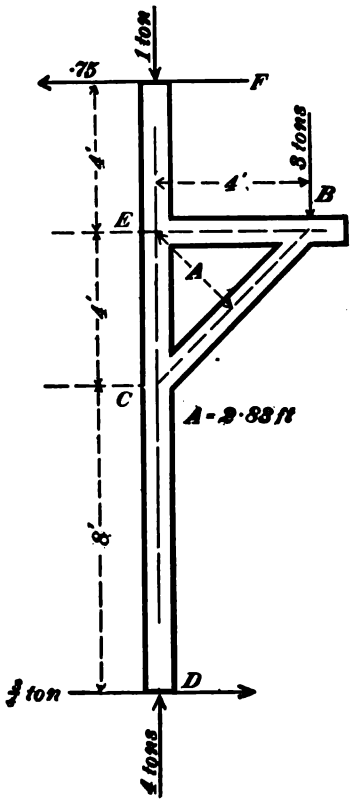

FIG. 49.

If this be done, and if we include all the forces, whether their leverage be zero or not, we have

[1 ton × 0 feet] − [¾ tons × 4 feet]
+ [3 tons × 0 feet]
+ [4·242 tons × 2·83 feet] − [¾ ton × 12 feet]
+ [4 tons × 0 feet] = 0 ton-feet.

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Let I = The second moment of the area, *i.e.*—the geometrical moment of inertia of the section (in inches^4).

Let y = The distance of the neutral axis from the extreme fibres (in inches).

Let f_b = The stress on the extreme fibres due to bending (in tons per square inch).

Let f_c = The direct compressive stress in tons per square inch $= \frac{L}{A}$

Let L = Total vertical load, including load on brackets and weight of pillar and brackets.

Let A = Area of pillar in square inches.

Let f_r = Total stress in tons per square inch $= f_b + f_c$.

The bending moment at C in Fig. 49 = $\frac{3}{4}$ tons × 8 feet = 6 ton-feet = 72 ton-inches.

The moment of resistance $= I\frac{f_b}{y}$ (see Part VI.);

$$\therefore f_b = \frac{y}{I} \times \textit{Bending Moment}$$

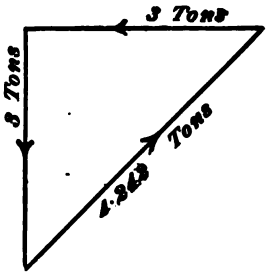

Fig. 50.

We have in these equations a means of finding f_b and f_c, and therefore we can discover the total stress at any cross-section.

If the length of a mild steel pillar, such as that in Fig. 49, is less than twelve times its least diameter, it will be quite safe if the maximum combined stress is at the rate of six tons per square inch.

If the ratio of length to least diameter is much in excess of 12 it will be necessary to ensure safety by reducing the working load per square inch. The rule is:—

By means of the ordinary pillar formula, design a pillar to carry an equivalent central load of $(f_b + f_c)$ A *tons.*

For the pillar shown in Fig. 49, the ratio of length to diameter is found by taking the overall length of the pillar from D to F, and dividing this by the diameter at right angles to the plane of the paper.

The diameter in the direction of the plane of the paper should of course be as large as possible, on account of the bending due to the great eccentricity of the load.

It is only under the most exceptional conditions that a ratio greater than twelve diameters should be permitted for pillars carrying gallery brackets, etc. If this ratio be greatly exceeded, the extravagance entailed can benefit nobody except the maker and the carrier, assuming these are both paid by tonnage.

Further Simplification of Radius of Gyration Formulæ.

To find the effective radius, *i.e.*, the so-called radius of gyration, of a strut or pillar, it is necessary to find the geometrical moment of inertia of the section, divide this by the cross-sectional area, and extract the square root of the quotient. If the section is a complex one, its moment of inertia can only be found by summing the moments of inertia of the component parts of the section. To do this correctly involves a knowledge of the Theorem of Parallel Axes. Now all this means a very lengthy and tedious calculation, demanding strict attention at every step. If, then, a rule can be found which will enable us to discover the radius of gyration by an operation so simple that it can in many cases be performed mentally, its advantages will be too obvious to require commendation. Such a rule I propose to explain; firstly, for cases where exact results may be obtained, and secondly, for those cases in which an approximation only is to be expected.

Let I = The second moment or geometrical moment of inertia, in inches^4.

Let A = Cross-sectional area, in inches^2.

Let r = Effective radius, or radius of equivalence, or radius of gyration in inches.

Let d = Diameter of section at right angles to the neutral axis (in inches).

Let b = Breadth of section in inches.

In the case of the circle, the value of I about a diameter $= \frac{\pi}{64}d^4$ and $A = \frac{\pi}{4}d^2$.

By Equation No. XXX on page 191 of Vol. II., $r = \sqrt{\frac{I}{A}}$.

Therefore for a circle,

$$r = \sqrt{\frac{\pi}{64}d^4 \div \frac{\pi}{4}d^2}$$

$$= \sqrt{\frac{I}{16}d^2} = \sqrt{\frac{I}{16}} \cdot d$$

$$= \frac{I}{4}d.$$

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For a circle, then, we can always discover the radius of gyration by mentally taking a quarter of the diameter.

For a rectangular beam,

$$I = \frac{1}{12} b d^3$$

$$A = b d$$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{1}{12} b d^3 \div b d}$$

$$= \sqrt{\frac{1}{12} d^2} = \sqrt{\frac{1}{12}} \cdot d$$

$$= \frac{1}{\sqrt{12}} d = \frac{d}{3{\cdot}45}$$

Since $r = \frac{d}{3{\cdot}45}$ we have only to multiply both sides by 3·45, and divide both sides by r to get the ratio given in Fig. 51. This ratio is true and exact, no matter what the size of the rectangle or circle may be.

Let the reader now take any complex section, and draw for himself five horizontal parallel lines across it; one through the centroid, representing the neutral axis, and two lines parallel to the neutral axis, and passing through the top and bottom of the section, and two lines at a distance equal to the effective radius, one on each side of the neutral axis. d is then the distance between the two extreme lines, and r is one-half the distance between the two intermediate lines. The distance between the two intermediate lines may be called the effective diameter or depth, to distinguish it from the extreme diameter or depth.

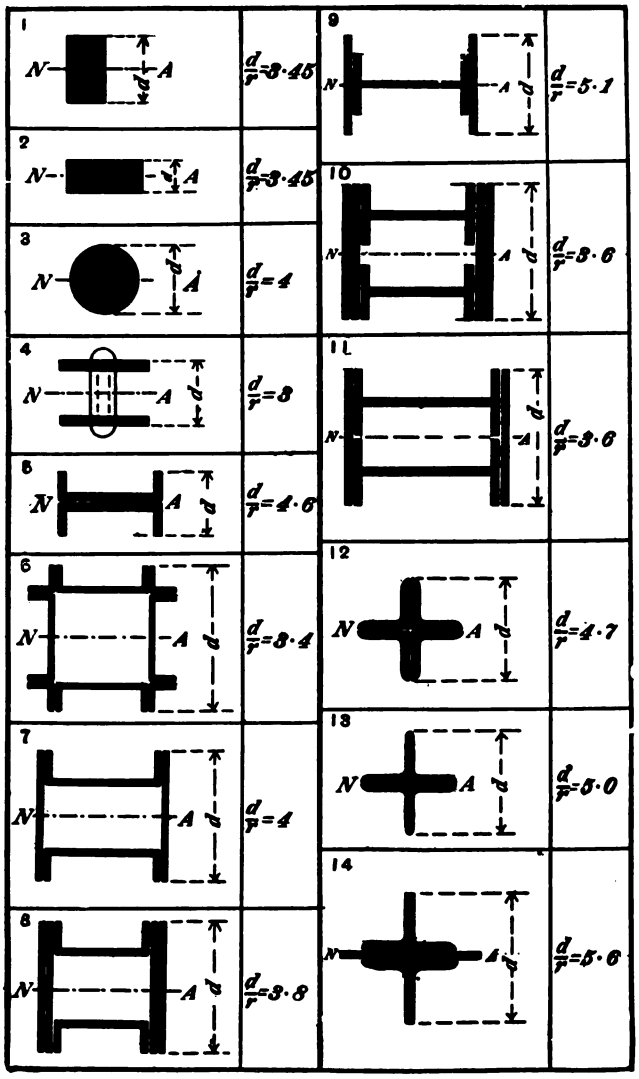

FIG. 51.—SECTIONS OF PILLARS, WITH VALUES OF THE RATIO d/r. r = radius of equivalence. NA, *neutral axis*.

Observe, then, that we may now define the effective radius of a strut as one-half the *effective* diameter of the strut.

We can, perhaps, then briefly describe the so-called radius of "gyration" as one-half the effective diameter.

If the reader can now imagine that he has taken several photographic enlargements, and several photographic reductions of this drawing I have asked him to make, he should be able to perceive that the ratio of d to r has not been affected by such enlargement or reduction. If now, rolled steel joists were all so proportioned that each one was an exact enlargement or reduction of all the rest, the mathematician would say that these sections were all "similar figures." Under these conditions, if we knew all the ratios for any one section, we could at that instant ascertain the value of the radii of gyration for all the rest, if only one other dimension were given for each, even though that other dimension were just the radius of the little curve joining the flange to the web. However, the market sections of rolled steel joists are so far from being "similar figures" in the mathematical sense, that even among the joists listed by the Engineering Standards

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Committee, the value of $\frac{l}{r}$ ranges from 4·2 to 4·9. This variation is so great that our approximate rule becomes valueless.

However, among more complex sections of any particular type, there is less variation in proportion, and our rules become safer. In the case of the section built up of four plates and two joists, out of twelve examples there was only a difference of about two per cent. between the extremes and the average. One or two of the better-class text-books have given these ratios for the simple rolled sections, such as ties, angles, etc.; but in July of this current year, the British Engineering Standards Committee published the list of sizes and properties of the approved sections, together with such complete tables as to render this $\frac{l}{r}$ approximation unnecessary for simple sections. Some such rule is, however, still a pressing need for complex sections, and I therefore submit the accompanying table (Fig. 51). It will, at least, form a ready check on the lengthier, though more exact methods. Sections 1, 2 and 3 are ratios obtained from the formula for I and A. No. 4 is from Rivington's Notes on Building Construction, Vol. IV. No. 5 is by Professor Pullen. The remainder represent averages from a great number of examples specially calculated by the author. To get the safe load on any pillar of the types shown in the table, we simply find r by dividing the diameter by the proper constant, and when we know r, we can find $\frac{l}{r}$. When $\frac{l}{r}$ is known, we can obtain the safe working load from the table in the previous issue of this magazine.

This table also reveals very clearly the relative advantages of the different sections from a theoretical point of view. The less the constant is, the greater is the effective radius in comparison with the diameter, and, therefore, the material is disposed more economically.

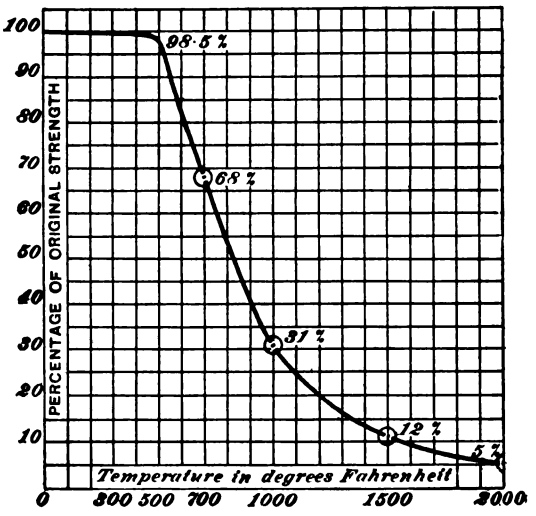

FIG. 52.—CURVE SHOWING THE EFFECT OF A HIGH TEMPERATURE ON THE STRENGTH OF STEELWORK.

EFFECT OF HEAT ON STRENGTH OF STEELWORK.

Because any particular material is not inflammable, it does not follow that this material is therefore fireproof. For example, lead is not inflammable, but it melts at such a low temperature that no one could call it fireproof. Mild steel is not inflammable, but it does not deserve the name of fireproof in the sense that brickwork does. With the heat common in conflagrations, unprotected steelwork may soften and fail.

I heard of one case where an iron beam had fallen, in a big fire, across an oak beam. The oak beam was charred and burnt to a certain depth, but sustained its load; whilst the iron girder had softened, and lay straddled over the wooden beam like an inverted U. It becomes necessary, then, to protect steel construction in buildings by means of cement, concrete, terra-cotta blocks, fire-resisting plaster, or other similar means.

Fig. No. 52 has been plotted from some figures given by M. Roelker, and shows the decrease in strength occasioned by increase of temperature. At the great fire in Tooley Street, Southwark, there was circumstantial evidence in the form of melted cast-iron work, showing that the temperature was in places as high as 2,500° F.

This passing reference to fire effects is given solely to accentuate the incompleteness of unprotected constructional steelwork for fire-resisting purposes.

(To be continued.)

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REVIEWS.

The Analysis of Steel-Works Materials. By Harry Brearley and Fred Ibbotson, B.Sc. pp. xvi. + 501. Illustrated with drawings and photo-micrographs. (London: Longmans, Green, & Co., 1902.) Price 14s. net.

This is a book which no chemist interested in the analysis of steel-works materials should be without. The authors exhibit a competent knowledge of analytical methods, combined with an intimate acquaintance with the conditions under which analyses must be carried out by a works chemist; consequently many accepted methods, which are long and laborious, or require delicate manipulation, or are wanting in accuracy, have been set aside for others not affected by these disadvantages. No method is described which has not been personally verified and tested for a considerable time, and in many cases the adequacy of the instructions given has been gauged by having an estimation carried out from it by an analyst with no previous experience of the particular process described. Further, as the account of each process was written, the operation itself was carried out by the authors, so as to ensure that no point of importance was missed.

Part I. deals with the analysis of steel; the methods of estimating the contained carbon, silicon, manganese, sulphur, phosphorus, chromium, nickel, tungsten, molybdenum, titanium, aluminium, copper, arsenic, iron, and other minor constituents are described. Part II. deals with the analysis of pig iron. Part III. contains a description of the methods to be used in analysing steel-making alloys, such as alloys of silicon, manganese, chromium, nickel, tungsten, molybdenum, vanadium, titanium, aluminium, and boron. Part IV. is devoted to rapid analyses at the furnace. The analysis of ores is described in Part V., the analysis of refractory materials in Part VI., and the analysis of slags in Part VII. Under the heading of "Analyses of Fuel," the methods of testing coal, coke, and gases are described in Part VIII. Part IX. is devoted to the analysis of boiler water, boiler scales, etc.; while the analysis of engineering alloys is considered in Part X. An interesting account of the microscopic analysis of steel is given in Part XI.; this account is illustrated by photo-micrographs, due to, or taken from, sections prepared by Professor J. O. Arnold. Part XII. consists of a short section on Pyrometery, contributed by Mr. A. M'William, A.R.S.M. Much useful information has been collected in Part XIII., under the heading of "Miscellaneous Notes." The very complete bibliography compiled by Mr. Brearley should be of great service to analysts, as affording a ready means of ascertaining the nature of the work already done in any particular branch of the subject. A useful index has been added.

Mechanics applied to Engineering. By John Goodman, Wh.Sc., M.I.C.E., M.I.M.E., Professor of Engineering in the University of Leeds. Fourth and enlarged edition. pp. viii. + 730, with 714 illustrations. (London: Longmans, Green & Co., 1904.) Price 9s. net.

This book has been written for engineers and students who already possess a fair knowledge of elementary mathematics and theoretical mechanics, and wish to apply their knowledge to engineering problems. A glance through its pages is sufficient to show that the method of treatment adopted is admirably adapted to the needs of those for whom the book was written: lucidly written and well illustrated, the book might well serve as a model for others of a like character. The author has aimed at producing a book which, so far as possible, is complete in itself; hence two introductory chapters are devoted to measurements, units, the elements of theoretical mechanics, and mensuration. These introductory chapters should prove very useful, as they free the reader from the necessity of referring to other works in order to refresh his memory on any elementary principle applied in the subsequent chapters. Exception may, however, be taken to the definition given of momentum as *quantity of motion* (p. 7); such definitions serve no useful purpose, and tend to confuse rather than enlighten the mind of the student, or else to generate a habit of resting content with a string of words which carry no definite meaning. Chapters III. to VII. deal in an able manner with moments, resolution of forces, mechanisms, dynamics of the steam engine, and friction. The theory of elasticity and its applications to the strength of machines and structures is dealt with in Chapters VIII. to XV.; Chapter XIV., which deals with the theory of torsion, should prove particularly useful. Hydraulics, hydraulic motors and machines, and pumps are investigated in Chapters XVI. to XVIII.; the sections devoted to the flow of liquids are extremely interesting, and are well illustrated by diagrams, and reproductions from some of Professor Hele Shaw's photographs. An elementary exposition of the fundamental principles of the differential and integral calculus is given

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in an appendix, which also contains much useful numerical information. Numerous examples to be worked by the reader, with answers, are given at the end of the book. An index of symbols, and a useful index, bring the volume to a close. There is no doubt that the present edition of Professor Goodman's book will be even more popular than the previous editions.

The Testing of Continuous-Current Machines in Laboratories and Test-Rooms: A Practical Work for Students and Engineers. By Charles Kinzbrunner, A.M.I.E.E. pp. x. + 326, with 249 illustrations. (London and New York: Harper and Brothers, 1904.) Price 6s. net.

In spite of the importance attaching to the testing of dynamo-electric machinery, but few books have been written on this subject. Mr. Kinzbrunner, as Lecturer on Electrical Engineering and Design at the Municipal School of Technology, Manchester, has had opportunities of organising and carrying out very exhaustive tests on all classes of electrical machinery; the present volume is an amplification of instructions for carrying out such tests, originally written out for the use of students at that institution. Though written primarily for students, it should prove extremely useful to engineers and others who are engaged in test-room work, or in installing, starting, and supervising electrical machinery. The first chapter contains a description of various types of switches, cut-outs, wires, and cables, starters and regulators, loading resistances, and measuring instruments. The second chapter is devoted to resistance measurements, including the measurement of the contact resistance of carbon and copper brushes. Measurements of armatures and field-winding temperatures, insulation resistance, and speed are described in Chapters III. to V. The determination of no-load and load characteristics is considered in Chapters VI. and VII.; Chapter VIII. is devoted to magnetic measurements of dynamos; while the efficiency of machines is exhaustively dealt with in Chapter IX. To the buyer of a dynamo or motor, a knowledge of its efficiency is of most importance; but the maker or designer feels a still greater interest in the study of the various sources of loss, since the knowledge thus gained may indicate points in which the design can be improved. Methods of separating the various losses in dynamos and motors are described in Chapter X.; a discussion of the relative advantages of the methods described would considerably add to the value of this chapter. Chapter XI. contains the Report of the Committee of Standardisation of the American Institute of Electrical Engineers, together with general information as to the most useful tests to be applied to machines.

An Introduction to the Study of Spectrum Analysis. By W. Marshall Watts, D.Sc., F.I.C. pp. viii. + 325, with a coloured frontispiece and 135 illustrations. (London: Longmans, Green & Co., 1904.) Price 10s. 6d. net.

In no branch of science has greater progress been made during recent times than in spectrum analysis; consequently, the need has been felt for a volume giving an up-to-date account of this subject, particularly as regards its most recent developments. The author of the volume before us was, perhaps, ill-advised in commencing with a discussion of the elementary principles of refraction, since all readers of the book would be familiar with these. In several parts of the book one cannot but regret that valuable space has been wasted on matter which can be found in almost any text-book on light, while the space might, with advantage, have been devoted to modern developments which are seldom adequately treated in text-books. Thus, less than four pages are devoted to a description of the "Zeeman effect," while ten pages are devoted to the elementary phenomena of refraction and dispersion. Chapter XI., which contains a discussion of the relations between the different lines of a spectrum, and between the lines of the spectra of allied elements, should prove very useful; while dealing with the subject of the determination of the atomic weights of elements from their spectra, the author has, unfortunately, omitted to refer to radium. The effects of pressure and density on the wave-length of the light emitted by a glowing gas are discussed on pp. 155 to 164; it is there pointed out that Rowland's tables of wave-lengths are slightly inaccurate; discrepancies between the wave-lengths of Fraunhofer lines and lines in the arc spectrum were considered by Rowland to be due to accidental errors, while, in all probability, a real difference exists. A brief description of the theory and use of Michelson's echelon diffraction grating is given in Chapter XIV. Pages 185 to 310 are occupied by wave-length tables for the Fraunhofer lines and the spectra of the various elements: these tables are unquestionably the most complete and exhaustive yet published, and will doubtless be of great service for purposes of reference.

Laboratory Handbook of Electro-Technology. By W. Brown, B.Sc., A.M.I.E.E., and R. G. Allen, A.R.C. Sc., A.I.E.E. pp. viii. + 159. (Dublin: Sealy, Bryers & Walter, 1904).

This book is intended to provide the student with a practical guide to his work in the laboratory. The descriptive text has been cut down to a minimum, since it is assumed that the student using this book in the laboratory will simultaneously attend lectures in which the principles underlying the experiments will be described. The first eight chapters are devoted to experimental measurements of resistance, insulation resistance, magnetic fields, the magnetisation of iron, capacity, and self and mutual induction. The last two chapters are devoted to experimental measurements of power, and the simpler measurements required in relation to a dynamo or motor. The book should prove of considerable assistance to teachers organising a first year course of experiments in electrical engineering.

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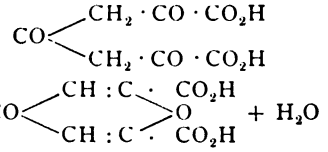
ANSWERS TO QUERIES

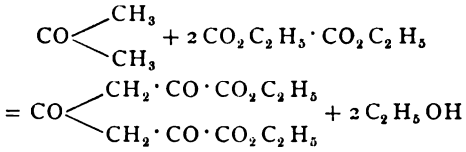
Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the* 10*th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

CHEMISTRY.—What is chelidonic acid? How is meconic acid related to it, and how has the probable constitution of the latter been ascertained?

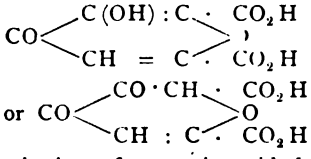
Chelidonic acid, or *pyrone-a_1a^1-dicarboxylic acid*, is a substance which occurs naturally in the "greater celandine" ("*Chelidonium majus*"), a member of the poppy tribe, and may be prepared synthetically from acetonedioxalic acid by the action of mineral acids



The diethyl ester of acetonedioxalic acid is made by the condensing action of sodium ethoxide on a mixture of acetone and ethyl oxalate



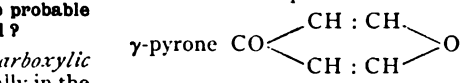
Meconic acid, which occurs in the opium poppy ("*Papsua somniferum*") appears to be very closely related to chelidonic acid, being probably a hydroxyderivative of that compound



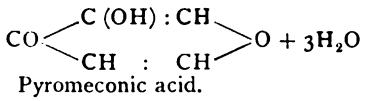
The constitution of meconic acid has been deduced from a considerable number of observations, of which the following are among the most important.

It is a hydroxydicarboxylic acid, for it yields a dimethyl ester which gives a reddish-violet colouration with ferric chloride; it is phenolic in character, and on treatment with methyl iodide and sodium hydroxide is converted into a methoxydicarboxylic acid, facts indicating that meconic acid contains two carbonyl groups and the phenol residue $\cdot C(OH):\dot{C}\cdot$

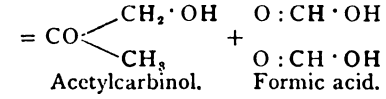
Meconic acid is easily converted by ammonia into a pyridine compound, which is in harmony with the assumption that it is a derivative of



When meconic acid is heated it loses first one and then two molecular proportions of carbon dioxide, yielding "comenic" and "pyromeconic" acids respectively. These two acids, as well as meconic acid itself, when heated with baryta water, give rise to an oily substance which is almost certainly a condensation product of acetylcarbinol $CH_3\cdot CO\cdot CH_2\cdot OH$ formed in the initial stage of the hydrolysis; because acetylcarbinol itself, after treatment with baryta water, gives the same material. As well as the product just mentioned, meconic acid yields two molecules of oxalic acid, comenic affords one molecule of oxalic and one of formic acid, whilst pyromeconic acid gives rise to two molecules of formic acid. The obvious explanation of this is that the carbonyl groups of meconic acid are removed in the form of two molecules of oxalic acid, comenic acid having only one carbonyl group affording but one molecule of oxalic acid; and pyromeconic acid, with no carbonyl group, gives no oxalic acid at all. The hydrolyses of pyromeconic acid and of meconic acid evidently proceed in the following way—

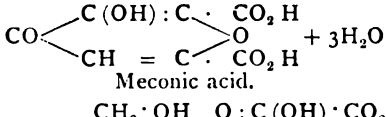


Pyromeconic acid.

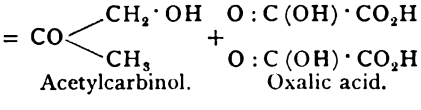


Acetylcarbinol. Formic acid.

and



Meconic acid.



Acetylcarbinol. Oxalic acid.

LUBRICANT.—What is the general composition of the soluble or miscible oils used for suds making in engineering works?

The most universal constituent is ordinary soft soap, as made by the Chiswick Soap Company,

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who make a speciality of this product. The proportions used are from one to two lbs. of soft soap per gallon of water. The solution is used cold; the colder the better. For ordinary brass work nothing is used, as it does not require lubricating. In the manufacture of screws, mineral oil is used in conjunction with soap.

Should you require any further information, kindly communicate with us.

We would remind you that soft soap is generally made by the use of potash in conjunction with tallow.

ELECTROSTATICS.—A thunder-cloud is over still water. What is the electrostatic surface density of the charge on the water, if this rises under the cloud 0·1 cm. above its previous level?—*London University, Final B.Sc.* 1893.

The thunder-cloud and the water act as the two plates of a plane condenser; the tubes of force leave either normally and extend straight across to the other. If σ represent the surface density (charge per unit area) of the water, $4\pi\sigma$ tubes of force (in electrostatic units) leave or enter a square centimeter of the water surface. Thus N, the number of tubes of force passing through a square centimeter of area placed parallel to the water surface, is given by the equation

$$N = 4\pi\sigma.$$

Now the tension per square centimeter exerted by the electric field is equal to $N^2/8\pi$ (*see* "The Electromagnetic Theory," pp. 580–585 in this number of TECHNICS. Since the electrostatic system of units are used, we substitute $\kappa = 1$). The tension of the tubes leaving the water raises its level by 0·1 cm.; therefore the tension per unit area in dynes is equal to the force of gravity on a cylinder of water 0·1 cm. in height and 1 square centimeter in sectional area, or 0·1 × 981 = 98·1 dynes.

$$\therefore\ 98{\cdot}1 = \frac{N^2}{8\pi} = \frac{(4\pi\sigma)^2}{8\pi} = 2\pi\sigma^2$$

$$\therefore\ \sigma = \sqrt{\frac{98{\cdot}1}{2\pi}} = \begin{cases} 3{\cdot}95 \text{ electrostatic units} \\ \text{per square centimeter.} \end{cases}$$

NICKEL SULPHIDE.—The following quotation is from Roscoe and Schorlemmer's treatise on Chemistry, Vol. II., page 1050. "When a solution of a nickel salt is heated with sodium thiosulphate, the monosulphide is obtained in the form of a dense black precipitate, which does not undergo alteration on exposure to the air, and is not acted upon by boiling hydrochloric acid." Will you kindly tell me how I can make three or four ounces of this monosulphide. My attempts so far only succeed in precipitating a *very* small proportion of the nickel present, even after long-continued heating.—NITROSO.

The solution of the nickel salt in water should be mixed with a small quantity of sodium acetate solution, any precipitate which is formed being removed by the addition of the smallest possible quantity of acetic acid to the boiling liquid. The latter is still kept at the boiling point, and pure crystallized sodium thiosulphate is added to it in small quantities at a time, and the black sulphide, which is somewhat slowly precipitated, may be removed by filtration of the hot liquid. If any large quantity of nickel remains in the filtrate, a further quantity of the sulphide may be obtained by raising the green solution to the boiling point once more, subsequently adding sodium thiosulphate as before; the precipitation may be hastened by the careful addition of a few drops of acetic acid occasionally, but care should be taken that too much is not added at once, as the sodium thiosulphate then deposits a considerable quantity of free sulphur, which renders the precipitate more awkward to deal with. At the conclusion of the operation, the united precipitates may be washed with hot water, dried and extracted with carbon disulphide to remove free sulphur.

TEXT-BOOKS.—Will you please inform me which are the best up-to-date text-books on alternating currents and polyphase working, in German and French. Also can you recommend me a good English text-book on chemistry? I am already in possession of Newth's work on the subject.

The following is a list of standard text-books on electrical engineering, in French and German:—

German.—Die Grandgesetze der Wechselstromtechnik, by Dr. Gustav Beneschke.

Handbuch der Elektrotechnik, Vol. IV., by Dr. F. Niethammer.

Drehstrom Motor, by Julius Henbach. 10 m. Springer, Berlin.

Elektromotoren für wechselstrom und Drehstrom, by G. Roessler, 7 m. Springer, Berlin.

French.—Pratique Industrielle des Courants monophasès alternatifs, by G. Chevrier. 9 fr. Carre & Naud.

Production et emploi des Courants alternatifs. By L. Barbillion. 2 fr. Carre & Naud.

Leçons d'Electrotechnique Général (Vol. II.) By P. Janet. 20 fr. Gauthier-Villars.

Distribution de l'Energie par Courants Polyphases. By J. Rodet. 15 fr. Gauthier-Villars.

Electrotechnique Appliquée. By A. Mauduit. 26 fr. 50. Ch. Dunod.

Electricité Industrielle. By D. Monnier. 25 frs.

In recommending a work on chemistry in English, very much depends on the purpose for which it is required and the price you are prepared to pay. Of inexpensive books, the work you name, *viz.*, Newth's, is excellent for facts and experimental data.

"Richter's Inorganic Chemistry" is a book of a higher class.

Holleman's (Inorganic Portion) is very pleasant reading, and forms a good introduction to the study of physical chemistry. This book is published by Chapman and Hall.

If you wish to launch out into further expense than any of these would involve, then we would recommend "Ostwald's Principles of Inorganic Chemistry." 18s. net. Macmillan and Co,

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ALTERNATOR PRESSURE REGULATION.—Describe fully the various methods employed in present-day practice for predetermining the "pressure regulation" of large alternators required to work on inductive load of given power factor. State which you consider the most satisfactory, and say why this method is to be preferred.—*Electric Lighting and Power Transmission. Honours*, 1904.

The regulation of an alternator is defined as *the ratio of the rise in voltage (from full load to no load at constant speed and excitation), to the full load voltage*, and the difference between the terminal P.D. on open circuit and that at full load-current is a factor which gives an indication of the quality and efficiency of the machine. Its pre-determination is to some extent complicated by the existence of variable inductive effects and armature reaction, the component drop in consequence being due principally to the demagnetising effect of the magneto-motive force (M.M.F.) of the armature current upon the magnetic circuit corresponding to the field winding. It is also obvious that pressure regulation depends upon the phase relations of the current and the open circuit E.M.F., and that the pressure induced in the armature, when the machine is loaded, is due to the resultant of a number of distinct and separate M.M.F.'s; the conditions of working are thus quite different from those existing when the machine is running on open circuit. The following are the M.M.F.'s which are active when a current traverses the armature :—

(*a*) The M.M.F. due to the exciting current of the alternator and giving rise to the main magnetic flux.

(*b*) The M.M.F. of the armature current which sets up two magnetic fluxes, *i.e.* (1) One traversing the same magnetic circuit as the exciting current, with which it is combined vectorially; it is obvious that the inductance (self-induction) due to this flux diminishes the pressure available at the terminals of the machine. (2) Another flux which leaks along the air gap and consequently traverses only a portion of the complete magnetic circuit of the machine. This leakage flux also gives rise to a certain amount of inductance, and the two inductances give rise to reactions which exist conjointly and exert similar effects; for this reason, and for the sake of convenience, Steinmetz has termed their combined effect the *synchronous reactance* of the armature.

If r_a denotes the armature resistance, and p L the synchronous reactance of the armature, then the expression

$$J_s = \sqrt{r_a^2 + p^2 L^2}$$

is termed the *synchronous impedance* of the armature. The experimental determination of this quantity is obtained from the open circuit characteristic curve E_o (Fig. 1) and the short circuit characteristic curve C_o. The former curve, which is similar to the magnetisation curve, gives the open-circuit E.M.F. corresponding to different excitations and is found experimentally; whilst the latter, which approximates to a

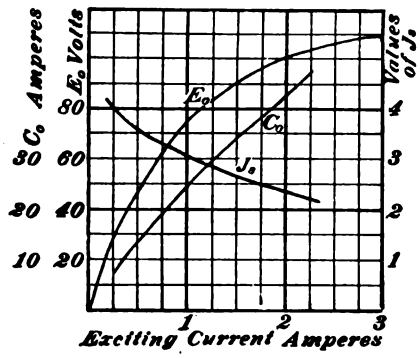

FIG. 1.
(ALTERNATOR PRESSURE REGULATION.)

straight line, gives the current corresponding to the different excitations when the terminals of the machine are short-circuited through a low resistance ammeter. The value of the synchronous impedance for a given excitation is given as the ratio of the open circuit E.M.F. and the short circuit current at the same excitation, or

$$J_s = \frac{E_o}{C_o}$$
$$= \sqrt{r_a^2 + p^2 L^2}$$
$$\therefore p L = \sqrt{J_s^2 - r_a^2}$$

It, however, must be observed that this numerical value is not the same as that obtained by passing an alternating current of known frequency through the armature at standstill. A third characteristic curve J_s is given in Fig. 1 to represent the synchronous impedance.

Behn-Eschenburg was one of the first to point out (see *Electrician*, July 26th, 1895) that with a knowledge of the two characteristics when running on no load and on short-circuit—*i.e.*, on the basis of a definite armature impedance—one may pre-determine the regulation of an alternator on loads of different power factor, assuming that the values of synchronous reactance and impedance obtained as above are the equivalent constant values of the constantly varying impedance and reactance of the armature, and may replace the same. In this method (Behn-Eschenburg's) the synchronous impedance is split up into the two components, resistance and reactance, and by taking different values of the

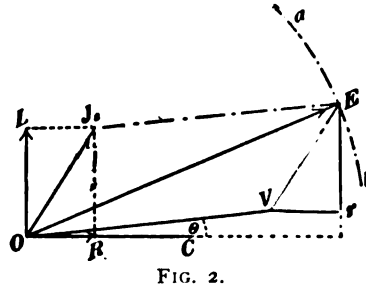

FIG. 2.
(ALTERNATOR PRESSURE REGULATION.)

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armature current, vector diagrams, similar to the one given in Fig. 2, may be readily constructed.

Let, for instance, cos θ denote the power-factor of the load, and θ be the phase relation between the current and terminal pressure. In Fig. 2 the vectors O R and O L are drawn in quadrature with each other to denote the resistance drop and reactance drop, rC and p LC respectively; then OJ_s denotes the synchronous impedance drop $C\sqrt{r_s^2 + p^2 L^2}$. O R produced is the direction of the current, and O V making an angle θ with OR is the phase of the terminal P.D. Since the open circuit E.M.F. E_o for the given excitation is known, from O as centre, and with length equal to E_o as radius, describe the arc a E b, and from J_s draw J_s E parallel to OV and cutting the arc a E b at E. Join OE and introduce the line EV equal and parallel to J_sO, cutting the line of the terminal P.D. at V. From V draw Vr equal and parallel to OR, and from E draw Er equal and parallel to OL. OV is then the terminal P.D. for the given current C and power-factor Cos θ. The general equation to the regulation curve of the machine under any load of power-factor Cos θ may be readily determined from this diagram.

Behn-Eschenburg's method consists in combining vectorially E.M.F.'s, whilst Rothert proposed a method which combines vectorially M.M.F.'s or ampere-turns, on the principle that the field ampere-turns may be divided into two portions (1) one employed in driving the current through the armature itself, and (2) the other in maintaining the given terminal pressure. The former portion is known from the short-circuit characteristic, and the latter from the open-circuit characteristic of the machine. The vector-diagram (Fig. 3) for this method is constructed as follows :—OE denotes the phase of the pressure and OC_1, in quadrature with it,

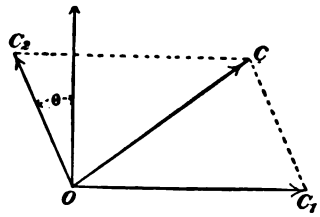

Fig. 3.
(Alternator Pressure Regulation.)

denotes the exciting current. The vector OC_2 is introduced so as to make an angle θ with OE, and an angle $(90° + \theta)$ with OC_1, of a length to represent the exciting current required to produce a short-circuit current equal to the given armature current, as given by the short-circuit characteristic curve. The resultant of OC_1 and OC_2 or OC_1 referred to the open-circuit characteristic curve gives the open-circuit E.M.F. corresponding to the exciting current OC. This open circuit E.M.F. represents the required value of the terminal P.D.

Another method introduced by Potier is a modification of that of Rothert, and is founded upon the principle of analysing the armature field into its components, *i.e.*, the armature leakage is separated from the armature reaction. The P.D., as determined by Rothert's method,

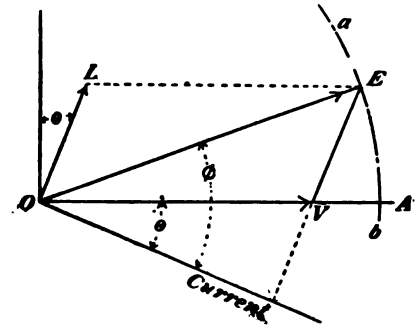

Fig. 4.
(Alternator Pressure Regulation.)

is compounded with the armature leakage E.M.F. p L$_s$ C. In Fig. 4, the arc a E b is described with a radius equal to the terminal P.D. (as determined by the previous method) about O as centre (Fig. 4) and OL equal to p L$_s$ C is introduced as shown. By drawing LE parallel to OA, and EV parallel and equal to OL, the P.D. OV is obtained. This diagram gives approximately the angle ϕ which the current makes with the E.M.F. OE, and by repeating the construction of Rothert's method (Fig. 3) another value of the P.D. is obtained, which by repeating the construction of Potier's method (Fig. 4) a closer approximation of the terminal P.D. OV is obtained.

The results obtained by the above methods are more or less approximate, and do not agree very closely with experimental results. It is obvious that the value of the synchronous impedance, as calculated from the open and short-circuit characteristics, comes out too large. This is due to the fact that, in so determining the value, the machine is working with a very much under-excited field or with a very excessive armature current, both of which circumstances would give rise to a larger amount of armature reaction than would occur under normal working conditions. With the Behn-Eschenburg method the regulation comes out worse than the actual regulation, whilst Rothert's method gives the theoretical value better than the practical value, and as already stated, Potier's method gives a closer approximation to the actual value than either of the others.

AERIAL ROPEWAY.—The sketch submitted herewith shows one span of a ropeway. The distance between the supports A and B = 270 feet. The gross load of bucket and contents = 10 cwt. Can you give me any information on the following points—

(1) A formula or method of finding the stress on the carrying rope with the load at any given point along the span and with varying degrees of sag or versed sine.

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(2) What is the maximum stress on each end of the carrying rope, with the load at A and travelling towards B, say at each ten yards along the rope?

(3) How can the exact position of the rope at every ten yards be obtained for any given position of this travelling load?

(4) What is the amount of sag or versed sine expressed in terms of the length of span which is usually adopted in wire ropeways?

(5) What is the tension on the guy ropes AC and BD?

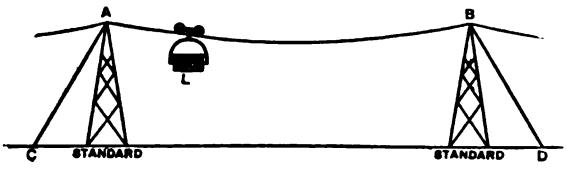

FIG. 1.—(WIRE ROPEWAY.)

While there are no extraneous loads on the cable the curve will be a catenary; and if the curvature is small, the tension in cwts. will be approximately $= \frac{W L}{8 D}$ where W = the weight of the rope between A and B in cwts. and where L = span [in feet] and D = sag [in feet].

When the weight of the bucket comes upon the cable, this loses nearly all its curvature and becomes more or less straight between the load and the supports.

This may be verified by experiments on a small scale, or by an inspection of photographs of existing ropeways.

It should be borne in mind that the load in the carriers may be four or five tons, while the rope may only weigh a few hundredweights, according to the span, etc.

Under these conditions the triangle of forces will give us a safe working solution; for by the wording of the first question we are permitted to assume any given sag, or camber.

In answer to the second question, let x = the distance in feet from the left support, and let T = the tension on the rope to the left of the load.

By the triangle of forces we obtain the following approximate values of T:—

x yds.	10 yds.	20	30	40	45	50	60	70	80
T cwts.	37·5 cwts.	42	43	46	50	46	43	42	37·5

The above values of T are based upon the following assumptions (1) That the stresses due to the weight of the rope are negligible in comparison with the stresses due to the loaded bucket. (2) That the length of the rope between the supports remains constant. (3) That the sag $= \frac{1}{20}$ span. With reference to the third question, it is usual, in ropeways having a fixed carrying rope and a separate hauling rope, to have one end of the fixed rope anchored down, and to have a straining or tightening gear fixed at the other end. There are usually rollers or pulleys on the tops of the intermediate trestles or supports. Without some such arrangement no adjustment of the sag of the cable on the intermediate spans would be possible. In taking out the table of stresses we assumed that the rope was fixed at the supports. Such an assumption does not represent the true state of affairs, but it gives an answer which is on the safe side, for any given sag. The pull of the hauling rope, changing as it does in slope or inclination, materially affects the position of the carrying rope and the path of the bucket. The exact position of the rope for every position of the load depends upon a number of factors which are quite beyond the control of the designer. For instance, the number and position of the trestles will depend largely upon geographical and topographical considerations. The precise aerial path of the buckets and the position of the rope will be affected by the number of spans; for the greater the number of spans and buckets, the less will any particular load affect the position of the rope in any particular span.

The position of the cable in any particular span also depends upon whether the buckets on adjoining spans happen to be full or empty; and, moreover, the man in charge of the tightening gear can modify the position of the rope throughout every span.

In reply to question 4, there can be no general rule for the amount of sag or versed sine expressed in terms of the length of span, because each case is judged on its own merits.

The sag will depend upon the nature of the intervening ground, whether rocky and uneven or flat, and upon the difference of level between any two consecutive supports. The gradient between two supports may vary from zero to a gradient of one in two. The sag will also depend upon the necessity of keeping the buckets at or near the level of the supports.

In the case of coaling ships by ropeway the deflection may occasionally be as much as one-fifth of the span.

The allowable camber will also depend upon the direction in which the load travels. If the load is being drawn uphill, too much sag on the carrying rope will increase the difficulty of steady and straight haulage and increase the stress on the hauling rope.

Over level ground a camber of one-twentieth of the span is sometimes adopted.

The less the sag the greater the stress, so that for any given rope, the greater the load the greater is the requisite initial sag. For the carrying ropes at least, it is good economy to use a high class of wire, with a high factor of safety, say 10. This will allow for wear and tear, and it will also allow for the foolishness of men who try to draw the cable too taut when there is no load on it, and then, when the load comes along, seem surprised at the result.

(4) The guy ropes AC and BD will only be required where the ropeway changes in direction. Observe the extra guy ropes on a telegraph pole

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where there is a turn in the road. The tension on the guy ropes can be found by the triangle of forces, by resolving the pulls on the carrying rope into one horizontal pull. Combine this resultant with the diagonal pull on guy and the upward thrust of the trestle. These three forces must lie in the same vertical plane. Actual trial will reveal the fact that the right position of the guy rope is pre-determined by the change in the direction of the ropeway.

FIXED CENTRE.—When a fluid is acted on by any forces, show that

$$dp = \rho(Xdx + Ydy + Zdz),$$

and explain the notation. Also show that when a homogeneous fluid is acted on by forces tending to fixed centres, its equilibrium is always possible. Explain the idea, "fixed centres."—(*3rd Stage, Mechanics of Fluids*, 1904.)

Let xyz be the co-ordinates of any point P in the fluid (referred to rectangular axes), X, Y, Z the components of the forces, per unit mass, at that point. Let Q be a point very near P, such that PQ is parallel to x, and call PQ, δx. Imagine a small right cylinder of cross section A, to be described about PQ. Then, since the fluid within the cylinder is in equilibrium, the forces acting on it parallel to the x axis must be in equilibrium. If $p + \delta p$ is the pressure at Q, the force over the end surface at Q is $(p + \delta p)$ A; A being very small at P, the force is pA. Hence, total force due to pressure is δp.A. If ρ denotes the mean density of the cylinder, its mass is ρ Aδx, and the external force (parallel to x) is ρ AδxX.

Hence δpA $= \rho$AδxX,

or, going to the limit,

$$\frac{\partial p}{\partial x} = \rho X.$$

The partial differentiation symbol is used to indicate that the change of pressure along the x axis is alone considered.

A similar investigation shows that

$$\frac{\partial p}{\partial y} = \rho Y, \text{ and } \frac{\partial p}{\partial z} = \rho Z.$$

But by the theory of potential differentiation,

$$dp = \frac{\partial p}{\partial x}dx + \frac{\partial p}{\partial y}dy + \frac{p}{\partial z}dz,$$

and hence

$$dp = \rho(Xdx + Ydy + Zdz).$$

Since the left side is a differential, it follows that the right side must be a complete differential, and hence for equilibrium to be possible, ρx, etc., must be obtainable by differentiation from some function of the co-ordinates $V = f(x, y, z)$, so that

$$\frac{\partial V}{\partial x} = \rho X, \frac{\partial V}{\partial y} = \rho Y, \frac{\partial V}{\partial z} = \rho Z.$$

(Whether it is possible to find this function V in any given case is another matter.)

For the second part of the question ρ is constant, and hence

$$\frac{\partial^2 V}{\partial y \partial x} = \rho \frac{\partial X}{\partial y} = \rho \frac{\partial Y}{\partial x},$$

so that equilibrium is possible if

$$\frac{\partial X}{\partial y} = \frac{\partial Y}{\partial x}\ ;\ \frac{\partial Y}{\partial z} = \frac{\partial Z}{\partial y}\ ;\ \frac{\partial Z}{\partial x} = \frac{\partial X}{\partial z} \quad . \quad (1)$$

By "fixed centres" is meant that any particle of the fluid is acted on by a number of forces, and that these forces are directed towards fixed points, the points or centres being the same for all particles. If we suppose, in addition, that these forces are functions of the distances of the particle from the centres (a proviso omitted in question), we can show that the equations (1) are satisfied.

Let r be distance of a particle (x, y, z) from a centre of force, and F (r) the force of attraction. Then, if a, b, c be the co-ordinates of the centre, the x component of the force is

$$F(r)\frac{x-a}{r},$$

$\frac{x-a}{r}$ being the cosine of the angle which r makes with the x axis, and hence

$$X = \Sigma\left\{F(r)\frac{x-a}{r}\right\}$$

$$Y = \Sigma\left\{F(r)\frac{y-b}{r}\right\}$$

$$Z = \Sigma\left\{F(r)\frac{z-c}{r}\right\}$$

Also

$$\frac{\partial X}{\partial y} = \Sigma\left\{F'(r)\frac{\partial r}{\partial y}\frac{x-a}{r} - F(r)\frac{x-a}{r^2}\frac{\partial r}{\partial y}\right\}$$

and

$$\frac{\partial Y}{\partial x} = \Sigma\left\{F'(r)\frac{\partial r}{\partial x}\frac{y-b}{r} - F(r)\frac{y-b}{r^2}\frac{\partial r}{\partial x}\right\}$$

But $r^2 = (x-a)^2 + (y-b)^2 + (z-c)^2$,

and therefore

$$r\frac{\partial r}{\partial x} = x - a,$$

$$r\frac{\partial r}{\partial y} = y - b,$$

and by substitution we see that $\frac{\partial X}{\partial y} = \frac{\partial Y}{\partial x}$.

Similarly we can show that the other conditions in (1) are satisfied, and hence the fluid is in equilibrium under the central forces.

RODRIGUE'S THEOREM. — Establish Rodrigue's Theorem that if n be a positive integer,

$$\sin nx = \frac{n}{1.3.5.\ldots.(2n-1)}\left\{\frac{1}{\sin x}\frac{d}{dx}\right\}^{n-1}(\sin x)^{2n-1}$$

(*Edwards' Differential Calculus*, page 77.)

By trial when $n = 2$, it is easily seen that the symbol $\left\{\frac{1}{\sin x}\frac{d}{dx}\right\}^{n-1}$ must mean that the operation $\left\{\frac{1}{\sin x}\frac{d}{dx}\right\}$ has to be performed $(n-1)$ times.

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Let $y = \cos x$ and $Y = \sin x$, then

$$\frac{1}{\sin x}\frac{d}{dx}Y^m = -\frac{d}{dy}Y^m$$
$$= -mY^{m-1}\frac{dY}{dy}$$
$$= myY^{m-2}.$$

For operations on powers of Y we have then the rule :— Decrease the index by 2 and multiply by y and the old index of Y.

Writing D for $\frac{d}{dy}$, we get

$$-DY^m = myY^{m-2}$$
$$D^2Y^m = m(m-2)y^2Y^{m-4} - mY^{m-2}$$
$$-D^3Y^m = m(m-2)(m-4)y^3Y^{m-6} - m(m-2).3yY^{m-4}$$
$$D^4Y^m = m....(m-6)y^4Y^{m-8} - m...(m-4)\frac{4.3}{2!}y^2Y^{m-6} + m(m-2)\frac{4.3.2.1}{4!}1.3Y^{m-4}$$
$$-D^5Y^m = m...(m-8)y^5Y^{m-10} - m...(m-6)\frac{5.4}{2!}y^3Y^{m-8} + m...(m-4)\frac{5.4.3.2}{4!}1.3yY^{m-6}$$
$$-D^6Y^m = m...(m-10)y^6Y^{m-12} - m...(m-8)\frac{6.5}{2!}y^4Y^{m-10} + m...(m-6)\frac{6.5.4.3}{4!}1.3y^2Y^{m-8} - m...(m-4)\frac{6!}{6!}1.3.5Y^{m-6}.$$

The mode in which the co-efficients are formed from those in the preceding operation is now obvious, so that we find,

$$(-1)^rD^rY^m$$
$$= m...(m-2r+2)y^rY^{m-2r} - m...(m-2r+4)\frac{r(r-1)}{2!}y^{r-2}Y^{m-2r+2} + m...(m-2r+6)\frac{r(r-1)(r-2)(r-3)}{4!}\times 1.3y^{r-4}Y^{m-2r+4} + (-1)^p m....(m-2r+2p+2)\frac{r....(r-2p+1)}{2p!}$$
$$\times 1.3.5....(2p-1)y^{r-2p}Y^{m-2r+2p} - (-1)^p m....(m-2r+2p+4)\frac{r....(r-2p-1)}{(2p+2)!}$$
$$\times 1.3.5....(2p+1)y^{r-2p-2}Y^{m-2r+2p+2} + ...$$

Hence the coefficient of $y^{r-2p-1}Y^{m-2r+2p}$ in the next operation, *viz.*, in $(-1)^{r+1}D^{r+1}Y^m$, is

$$-(-1)^p\left\{\frac{m...(m-2r+2p+2)}{(2p)!}\times r...(r-2p)\times 1.3.5(2p-1)\right\}\left\{1+\frac{(2p+1)(r-2p-1)}{(2p+1)(2p+2)}\right\}$$
$$= -(-1)^p\frac{m....(m-2r+2p+2)}{(2p+2)!}(r+1)r...\times(r-2p)\times 1.3.5....(2p+1).$$

The law of formation has thus been proved in general.

Putting in given values for r and m, we have

$$\left(\frac{1}{\sin x}\frac{d}{dx}\right)^{n-1}(\sin x)^{2n-1}$$
$$= (2n-1)(2n-3)...3y^{n-1}Y - (2n-1)(2n-3)...5\frac{(n-1)(n-2)}{2!}y^{n-3}Y^3 + (2n-1)(2n-3)...7\frac{(n-1)(n-2)(n-3)(n-4)}{4!}\times 1.3y^{n-5}Y^5 - (2n-1)(2n-3)...9\frac{(n-1)(n-2)...(n-6)}{6!}\times 1.3.5y^{n-7}Y^7 + ...$$

On multiplying by $\frac{n}{1.3.5...(2n-1)}$ we obtain

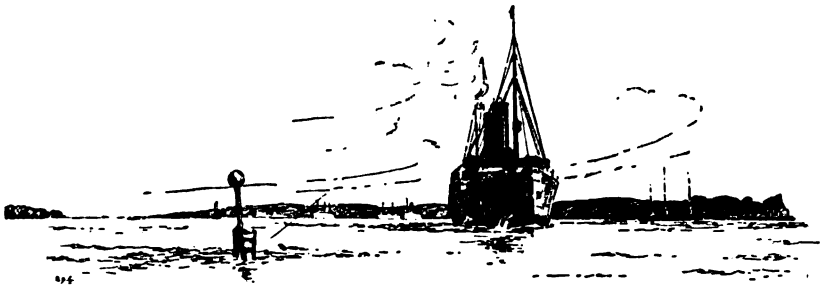
$$\frac{n}{1.3..(2n-1)}\left(\frac{1}{\sin x}\frac{d}{dx}\right)^{n-1}(2x)^{2n-1} = ny^{n-1}Y - \frac{n(n-1)(n-2)}{3(2)!}y^{n-3}Y^3 + \frac{n(n-1)...(n-4)}{5(4)!}y^{n-5}Y^5 - ...$$

Now $(y + iY)^n = \cos nx + i\sin nx$ (De Moivre) where $i = \sqrt{-1}$.

Hence, expanding the left-hand side, and equating the multiples of i on both sides, we obtain

$$\sin nx = ny^{n-1}Y - \frac{n(n-1)(n-2)}{3!}y^{n-3}Y^3 + ...$$

and Rodrigue's Theorem is established.



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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded to the "Technics" Prizeman.

£22 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 108 competitions have been given in the preceding eleven numbers of TECHNICS.

The present number contains particulars of 6 competitions, for which money prizes amounting, in the aggregate, to £22 will be awarded.

A prize of £200 in cash, and a Gold Medal will be awarded to the competitor who has shown the most care, thought, and accuracy in the competitions from January to December, 1904.

£22 IN PRIZES.

General Rules.

Competitors are requested to note the following rules :—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must be executed in black ink, and not shaded in wash, or coloured.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, TECHNICS, 12, Burleigh Street, Strand, W.C., and must reach these offices not later than January 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

CHEMICAL ENGINEERING.

£3 *for the best answer.*

Describe the latest developments in the manufacture of white lead, giving diagrams of the plant used.

MECHANICAL ENGINEERING.

£3 *for the best answer.*

Explain the principle on which the injector acts, and give diagrams with descriptions of the latest forms of injectors.

COTTON SPINNING.

£3 *for the best answer.*

Explain the object of "opening" cotton, and describe the best forms of cotton openers, with diagrams.

ELECTRICAL ENGINEERING.

£3 *for the best answer.*

Give diagrams of the best forms of controllers for traction motors, explaining clearly their mode of action.

ELECTRO-MAGNETIC THEORY.

£3, £1 10s., *and* 10s. *for the three best sets of answers in order of merit.*

1. Express the pull per square centimeter on either plate of a plane condenser in terms of the difference of potential between the plates, and the distance separating them. Hence explain the principle of action of the absolute electrometer.

2. A condenser is composed of two given plates kept at a constant distance apart. The charge of the condenser is constant : show that a slab of dielectric placed between the plates will not alter the pull per square centimeter on either plate, but if the space between the plates is completely filled with a liquid dielectric of Sp. Ind. Cap. = K, the pull per square centimeter on either plate is diminished in the ratio 1 : K.

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3. In Question 2, if the potential and not the charge is kept constant, show that the pull per square centimeter on either plate is increased in the ratio K : 1 by filling the space between the plates with a liquid dielectric of Sp. Ind. Cap. = K; while a smaller increase in the pull is produced by placing a thin slab of dielectric of Sp. Ind. Cap. = K between the plates instead of the liquid dielectric.

4. A thin disc of soft iron, when placed flat on the plane pole of a strong magnet, is found not to be attracted to the pole; when placed on edge on the pole, a strong attraction is exerted. Explain this in terms of the distribution of tubes of force.

THEORY OF STRUCTURAL DESIGN.

£3, £1 10s., and 10s. for the three best sets of answers in order of merit.

1. If an unprotected steel girder is designed with a factor of safety of four, and is accidentally exposed to the heat of a conflagration, at what temperature, in degrees Fahrenheit, would you expect the girder to collapse? State what assumptions underlie your answer.

2. Design a built-up steel pillar, with a projecting arm or bracket on the side, from the following particulars: Height of pillar, 18 feet; central load, 60 tons; projection of bracket, 3 feet; height of top of bracket, 9 feet; load on extremity of bracket, 1 ton. Other details are left to your own discretion. Calculations should be submitted with the design. The details of the cross-section, and cap and base and bracket should be drawn to a scale of $1\frac{1}{2}$ inches = 1 foot. The general drawing of the pillar should be to a scale of $\frac{1}{2}$ inch = 1 foot.

3. What is the purpose of bolting pillars down to their bases?

4. A continuous girder is supported by a series of built-up mild steel pillars. The pillars rest upon concrete foundation blocks, which may have slight accidental variations in height. What measures can be taken, either at the time of designing or during erection, to ensure the pillar caps being in vertical and horizontal alignment?

RESULTS OF SEPTEMBER COMPETITIONS.

No. 1—PHYSICS.

PRIZE, £3.—Divided equally between two competitors:

Samuel Lees, 1, Trafalgar Street, Broughton, Manchester; Gordon S. Hardy, St. John's College, Cambridge.

SPECIAL HONOURABLE MENTION:—H. H. Francis Hyndman; S. Irwin Crookes; Harry Hutchinson; Edgar P. Hedley; R. T. G. French;

HONOURABLE MENTION:—W. G. Poupard; John F. Punch; R. M. Sheppard; S. R. Tyssen; D. Fulton; Harold Slicer.

No. 2—ELECTRICAL ENGINEERING.

PRIZE, £3.—Percy Alfred Spalding, 14, Torrington Square, W.C.

SPECIAL HONOURABLE MENTION:— John W. Alexander; S. Irwin Crookes; R. M. Sheppard; P. E. Banting; O. Faber.

HONOURABLE MENTION:—Christopher Hargreaves; Joseph Rafton; Frank Shaw; John F. Punch; H. A. Stewart.

No. 3—MECHANICAL ENGINEERING.

PRIZE, £3.—Thornton Knowles, 21, Benthal Road, Stoke Newington, N.

SPECIAL HONOURABLE MENTION:—A. Brierley; Harold Slicer; Albert George Long; Frederic Stones; J. E. Tytler.

HONOURABLE MENTION:—A. G. Lee; W. E. Dommett; Edwin Roscoe; A. Richards; G. Lees; H. G. Lester; K. Bonallo; F. L. Berry.

No. 4—CHEMISTRY.

PRIZE, £3.—B J. Eaton, 37, Belitha Villas, Barnsbury Park, N.

SPECIAL HONOURABLE MENTION:—R. H. Greaves; F. H. Hurren; Fred C. A. H. Lantsberry.

HONOURABLE MENTION:—Harry Hutchinson, A. G. Lee; Geo. J. Denbigh; H. H. Francis Hyndman; David R. Pye; G. W. James.

No. 5—INSTRUMENT DESIGN.

PRIZE, £3.—Fredk. J. Cooper, A.Sc., Senior Science Master, Municipal Technical School, Nelson, Lancs.

SPECIAL HONOURABLE MENTION:—Harold Slicer; H. H. Francis Hyndman; S. Irwin Crookes; Arthur Gadd.

HONOURABLE MENTION:—E. Crosland; Ernest W. Sanders.

No. 6—STRUCTURAL DESIGN.

PRIZE, £5.—Arthur Gadd, 5, Pine Grove, Victoria Park, Manchester.

SPECIAL HONOURABLE MENTION:—D. E. Synan; O. Faber.

HONOURABLE MENTION:—Harold Slicer; Frederic Stones; K. Bonallo; Hugh MacEwan.

No. 7—COTTON SPINNING.

This prize has been equally divided between two competitors: Abraham Brierley, 9, Belgrave Street, Rochdale; J. E. Tytler, 13, Hartley Street, Levenshulme, Manchester.

SPECIAL HONOURABLE MENTION:—George A. Barlow; Fred Buckley; Frederic Stones; R. Marcroft.

HONOURABLE MENTION:—William A. Walsh; Arthur Rowbottom; Herbert Wroe.

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PERSONAL ITEMS.

IT has frequently been stated that the aniline dye industry, inaugurated by a British inventor, has passed out of British hands. It is, therefore, with the greatest pleasure that we hear that the British firm of Messrs. Levinstein, Ltd., of Manchester, has secured the first prize at the St. Louis Exhibition for its excellent exhibit of aniline dye-stuffs and coal-tar products. This affords a striking proof of recent advance due to accurate scientific research. It is stated that the small success of the aniline dye industry in Great Britain is due more to the costliness of alcohol, resulting from the duty on this substance, than from any other cause.

MR. JAMES ANDERSON, Manager of the Sandwich, Windsor, and Amherstbury Railway, Windsor, Ontario, some little time back reported a most remarkable life record of a Westinghouse 12-A railway motor under his charge. It has been in constant operation for a period of eight years, covering during that time a distance of approximately 450,000 miles; and beyond the replacement of brushes, remetalling of bearings, and turning up of the commutator, has not cost a penny for repairs. The armature and field coils are intact, and the only signs of wear are on the commutator, which has been reduced $\frac{3}{8}$" by trueing up. The wearing depth of the segments is $\frac{1}{4}$", so that if the winding holds out, as there is every reason to expect it will, the motor should last another eight years, and double its already remarkable mileage. We understand there are several other motors of the same type working on this line that hold very nearly the same record, and have been equally free from serious repairs. They are all operated in single equipment and under 18-feet cars, and, as the road is practically level and without sharp curves, the conditions are somewhat favourable.

IN a paragraph describing the useful flexible curves made by Mr. Wm. J. Brooks, which appeared in the November number of TECHNICS (p. 482,) the address of Mr. Brooks was erroneously given as 33, Fitzroy Square, instead of 33, *Fitzroy Street*.

THE Civil and Mechanical Engineers' Society has changed its offices to 25, Victoria Street, Westminster.

A CHRISTMAS course of lectures, adapted to a juvenile auditory, will be delivered at the Royal Institution, Albemarle Street, Piccadilly, by Mr. Henry Cunynghame, C.B., on "Ancient and Modern Methods of Measuring Time" (experimentally illustrated). The dates of the lectures are December 27th, 29th, and 31st, 1904; January 3rd, 5th, and 7th, 1905.

IN face of severe competition, the Wolseley Tool and Motor Car Company, of Birmingham, has secured the order for a large six-cylinder petrol engine for the first of the new electric railway coaches of the General Electric Company, of Schenectady, New York.

A REMARKABLE tunnel is being constructed at Niagara Falls, by the Toronto and Niagara Power Company. This tunnel, when completed, will be 700 yards long, and will extend beneath the Niagara River and behind the Great Horseshoe Fall. A shaft has been sunk beside the river, and the tunnel commenced; an opening will be made in the front of the precipice, in front of which falls a sheet of water twelve feet thick.

A LIMITED number of scholarships and of teacherships-in-training, tenable at the Royal College of Science, Dublin, will be offered for competition among students of science and technology in 1905. The scholarships are of the value of £50 per annum, and, in addition, entitle the holder to free instruction during the associate course, and third-class railway fare for one journey each session to and from Dublin. A teachership-in-training entitles the holder to free instruction during the associate course, a maintenance allowance of 21*s*. per week for the session of about forty weeks each year, and third-class railway fare for one journey each session to and from Dublin. Candidates must have been born in Ireland, or have been resident in Ireland for three years prior to June 1st, 1905. Forms of application can be obtained after February 1st, 1905, from the Secretary, Department of Agriculture and Technical Instruction for Ireland, Upper Merrion Street, Dublin, and must be returned before April 29th, 1905.

MR. SIDNEY H. WELLS and the Rev. James Went have accepted the invitation of the President of the Board of Education to serve on the Consultative Committee in place of Professor Henry E. Armstrong and the Rev. Dr. Gow, who retire in accordance with the terms of the Order in Council by which the Committee was constituted.

MR. R. BORLASE MATTHEWS, author of the article on "Arc Light Carbons," which appeared in the September number of TECHNICS (Vol. II., pp. 283—287), has written to say that the temperature of the ovens, given on page 285, is unfortunately incorrect. The Celsius and Centigrade scales of temperature are, of course, identical, so that the temperature of the ovens ranges from 1,300° C. to 1,800° C., instead of from 1,625° C. to 2,250° C. as stated.

IN a paper read before the British Association, Mr. Campbell Swinton gave some statistics as to the water power now actually used for generating electricity: 1,500,000 h.p. is used for the purpose, nearly one-third of this total being used in the United States. The figure for Great Britain is 12,000 h.p. Mr. Swinton estimates that the coal saved by the use of water power at present amounts to 12,000,000 tons per year.

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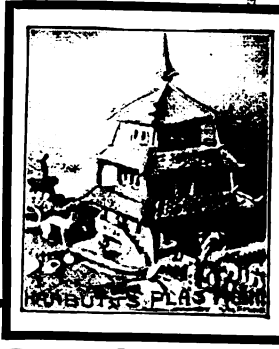

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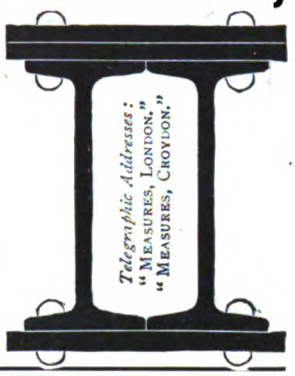

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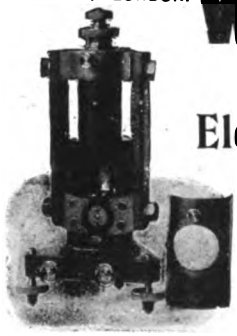

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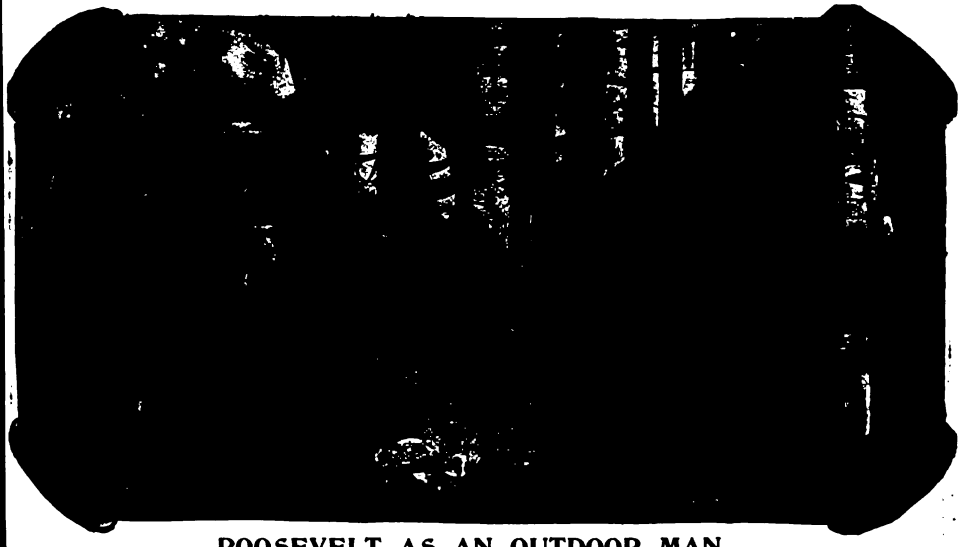

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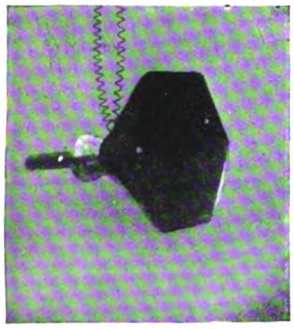

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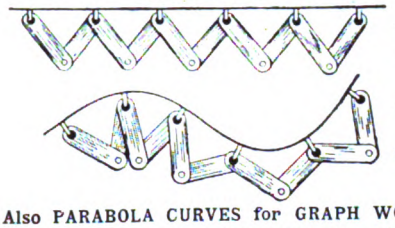

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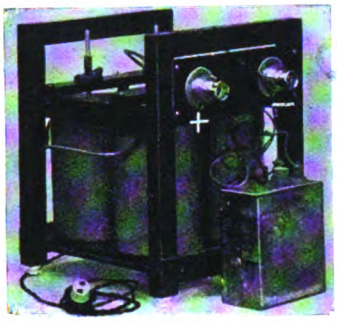

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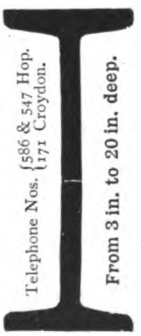

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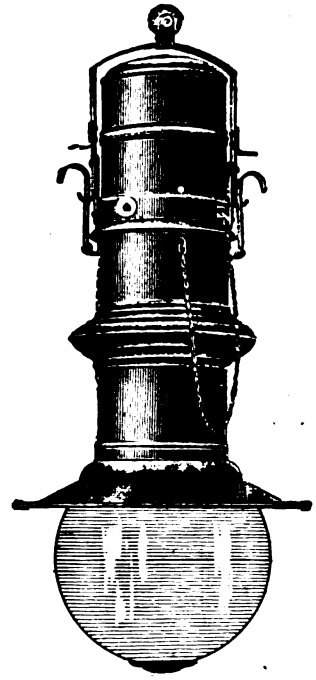

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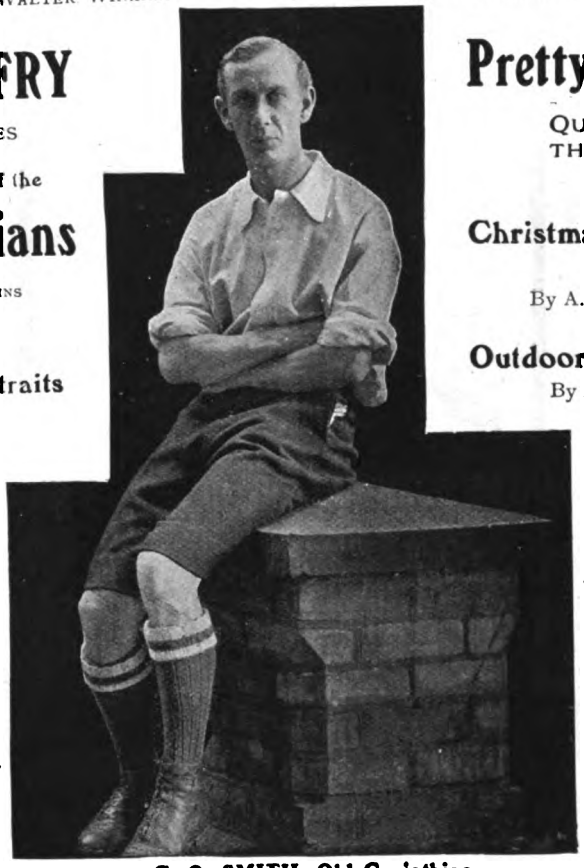

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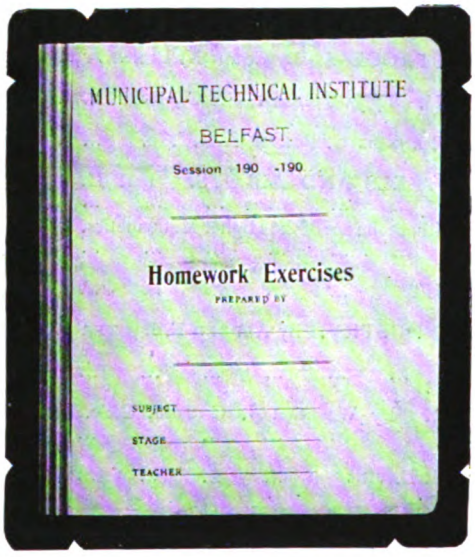

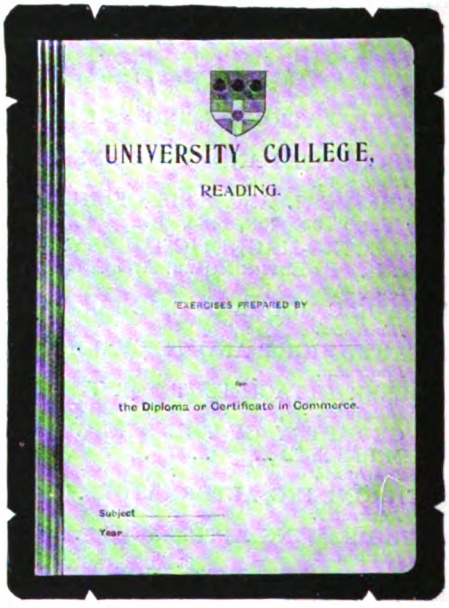

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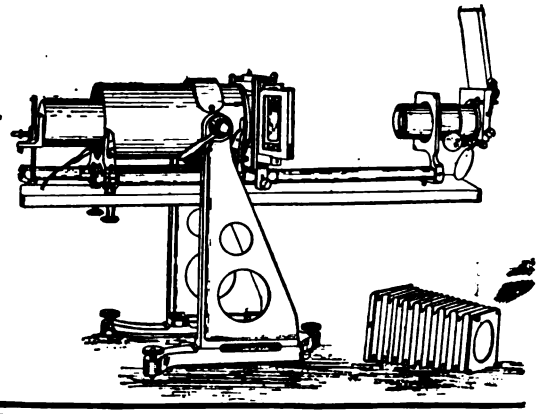

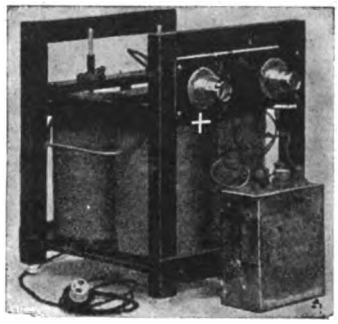

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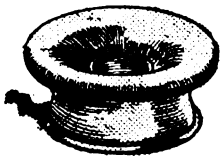

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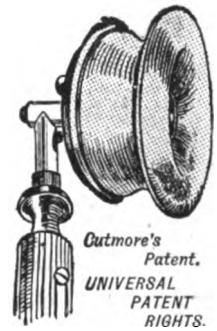

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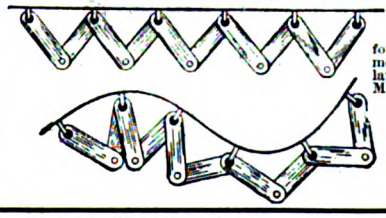

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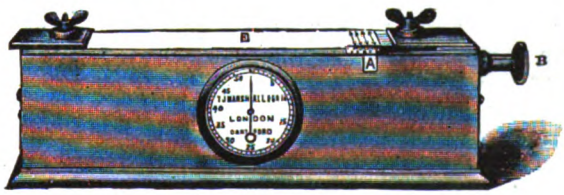

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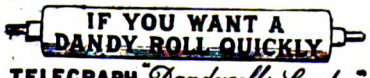

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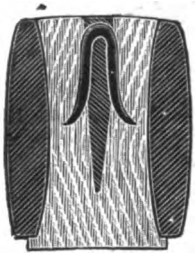

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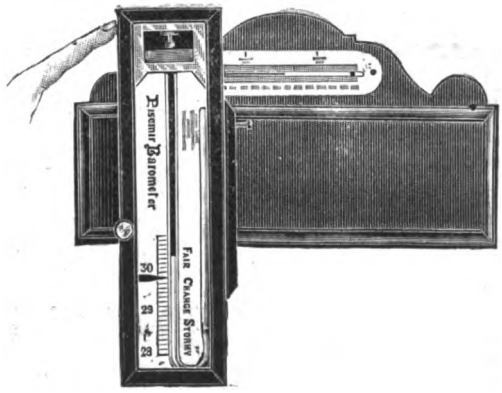

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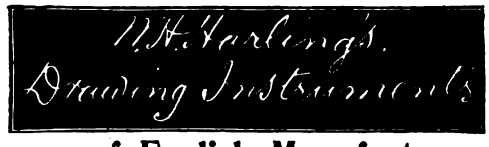

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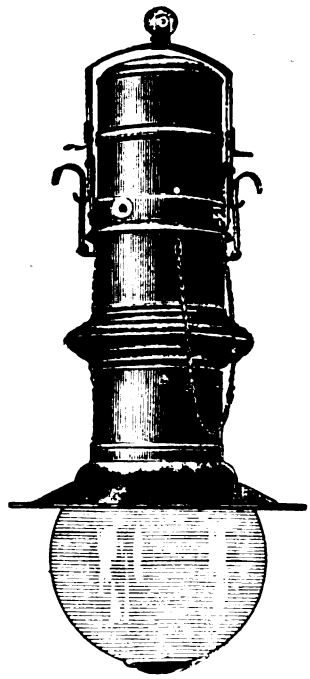

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A MAGAZINE TO AID TECHNICAL PROGRESS.

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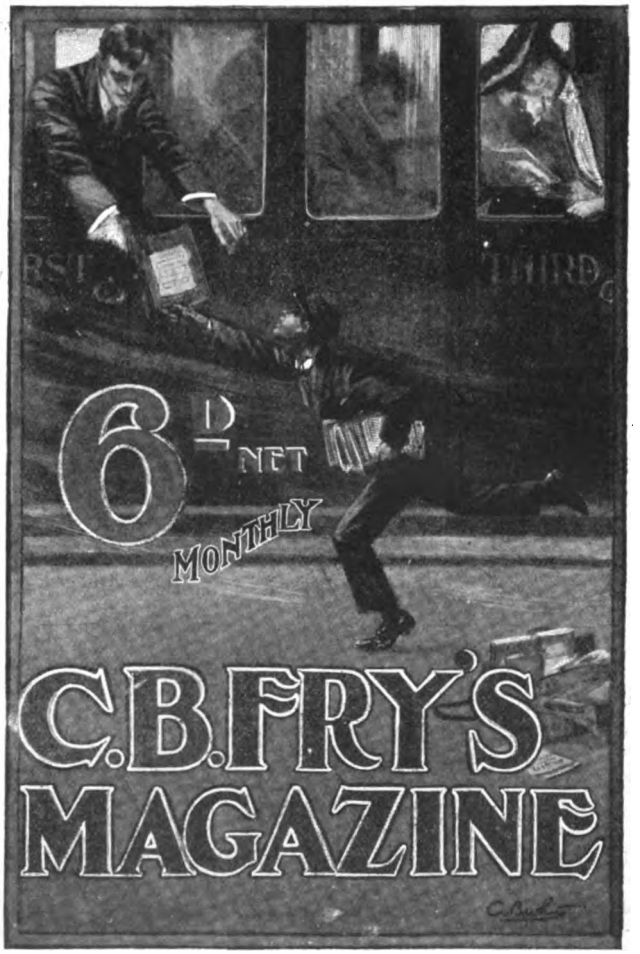

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